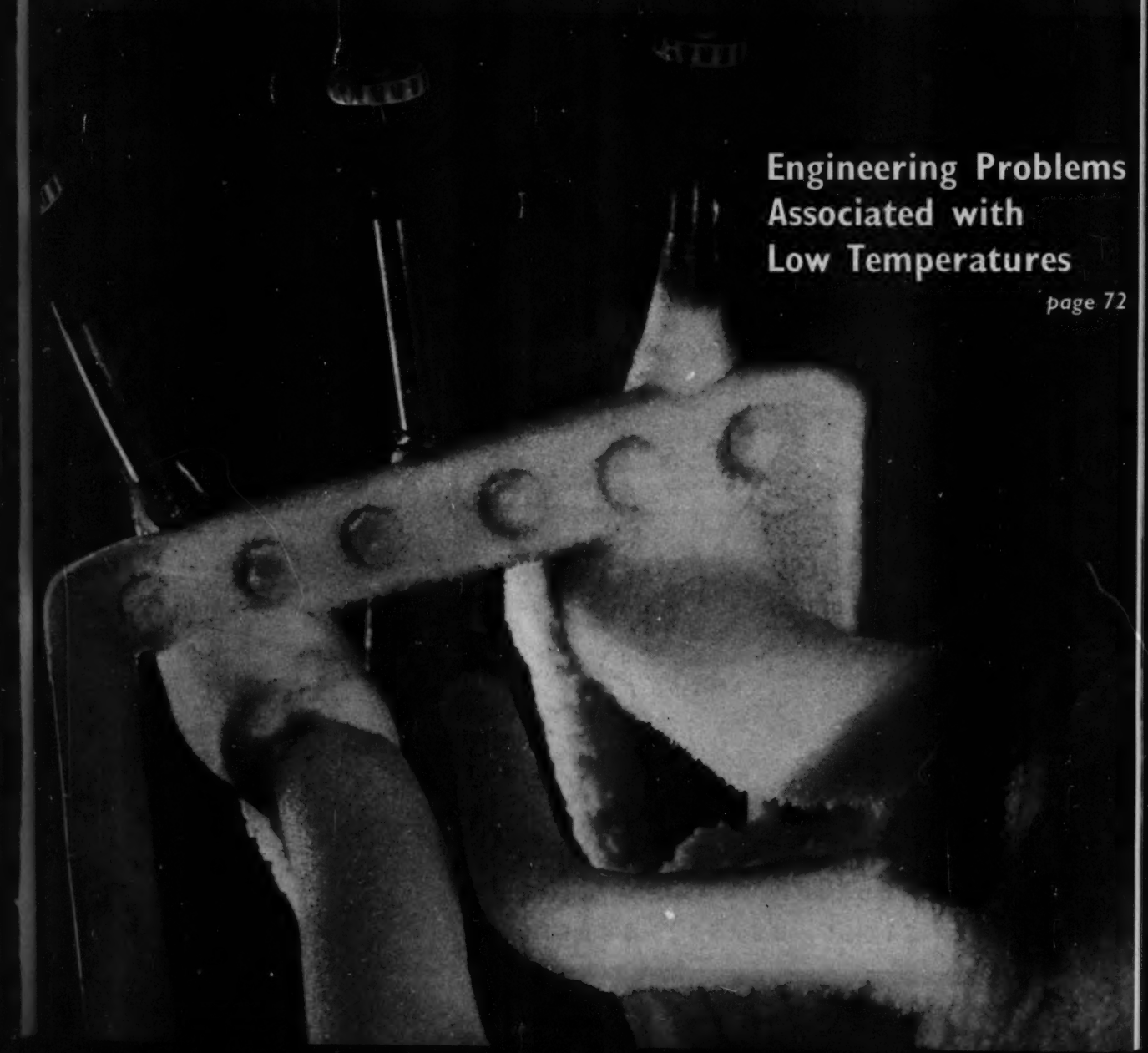
ngineering Materials and Design



Engineering Problems Associated with Low Temperatures

page 72

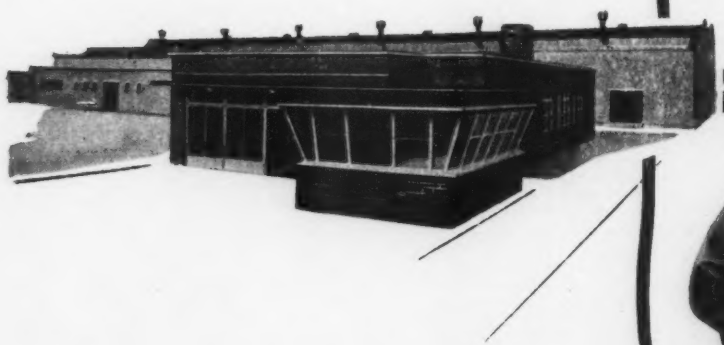
EMD 391 for further information

BUILD YOUR EFFICIENCY WITH

OSBORN PRODUCTS

Integrated experience from over a century of craftsmanship has made the name of *Osborn* world famous as a hallmark of quality in the manufacture of fine steels and steel products.

Products in alloy, stainless and tool steels are manufactured throughout within the same organisation, and include castings by general foundry and precision methods, forgings and engineers' cutting tools, etc.



STEELMAKERS · STEELFOUNDERS · ENGINEERS' TOOLMAKERS

SAMUEL OSBORN & CO., LIMITED

CLYDE STEEL WORKS, SHEFFIELD

Engineering Materials and Design

★ *The Magazine for Engineering Designers*

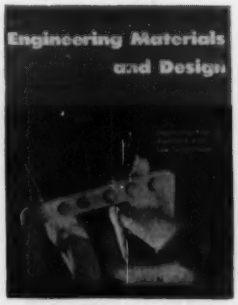
A HEYWOOD PUBLICATION

Vol. 2 No. 2 February 1959

EDITOR
H. R. Heap, B.Sc., A.M.I.E.E.

TECHNICAL EDITOR
R. D. Cullum, M.I.E.D., A.R.Ae.S., M.I.A.S.

ASSISTANT EDITORS
F. R. Terrell
P. Burton



COVER—Valves specially designed for low temperatures to prevent freezing up. (Photo: British Oxygen Research & Dev. Ltd.)

Published monthly by HEYWOOD & COMPANY LTD., Drury House, Russell Street, London, W.C.2 (Tel.: TEMple Bar 3422), on the 15th of the preceding month. Annual subscription 35s. sterling per annum ($5.25, U.S.A. and Canada) throughout the world. Single copies to order from all newsagents and bookstalls, 2s. 6d. each (by post from the publishers, 3s. 0d. each). BRANCH OFFICES: Royal Buildings, 2 Mosley Street, Manchester, 2, Tel.: Central 9935; Bayliss House, Hurst Street, Birmingham, Tel.: Midland 5786; 52 St. Enoch Square Glasgow, Tel.: City 3492; 527 Madison Avenue, New York 22, N.Y., Tel.: Plaza 9-1171.

© Heywood & Company Ltd., 1959. Must not be reproduced without written permission.

ISSUE AT A GLANCE

page

ENGINEERING PROBLEMS ASSOCIATED WITH LOW TEMPERATURES ... 72
Effect of low temperatures on conventional materials.
By **D. H. Tantam**, A.M.I.Mech.E.

CORROSION BEHAVIOUR OF SOME OF THE NEWER METALS 78
Tantalum, niobium, titanium, zirconium and beryllium.
By **N. P. Inglis**, Ph.D., M.Eng., M.I.Mech.E., F.I.M., and **J. B. Cotton**, A.M.C.T., A.R.I.C.

INDUSTRIAL DESIGN IN ENGINEERING 82
Integrating appearance and functional aspects.
By **R. M. S. Kay**, B.Sc. Tech., D.A.A., F.R.S.A.

SELECTION OF AXIAL SHAFT SEALS 90
Survey of types and applications of face-type seals.
By **P. L. McIlwraith**, A.M.I.Prod.E., A.I.Pat.I.

DRAWING OFFICE SYSTEMS 95
Towards greater simplification of filing and reference.
By **F. Kingsman**, A.M.I.E.D.

METAL BONDING WITH THERMOSETTING ADHESIVES 98
Its merits compared with more traditional techniques.
By **E. J. Catchpole**, M.S.In.A.E., B.Sc. (Eng.), A.F.R.Ae.S., M.I.A.S.

HEAT INSULATION WITH ALUMINIUM FOIL 102
Applications where its properties are of special value.

OTHER FEATURES

Semi-reflecting Glass Gives Infra-red Protection 77

Ferrite Memory Frame for Electronic Computers 81

New Ideas in Design 87

Designer's Notebook 105

V-belt Selection: Data Sheet 106

REGULAR FEATURES

Materials in the News ... 65

Editorial 71

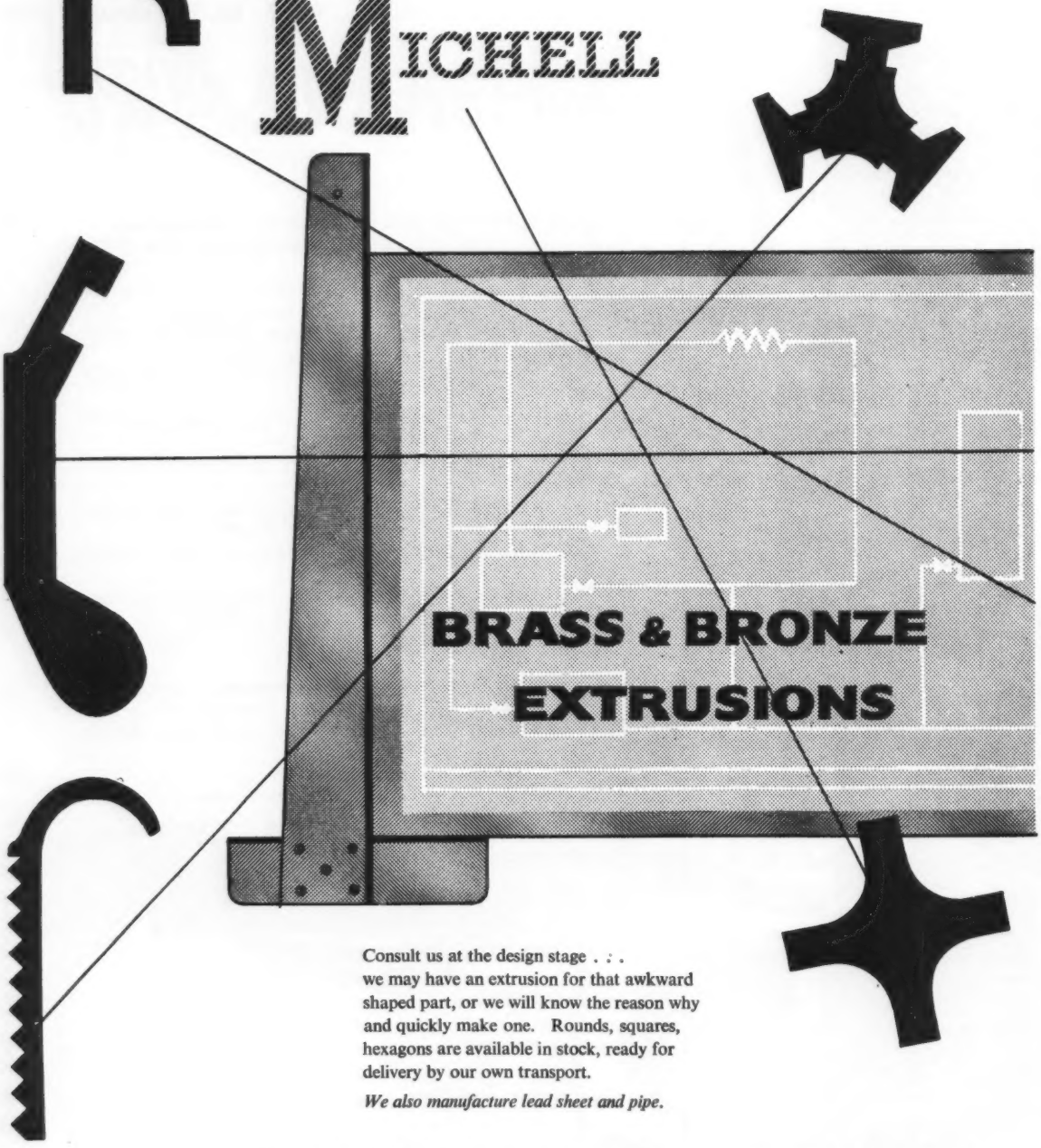
American Letter 111

What's New in Materials and Components 112

News of Industry 121

EMD 392 for further information

HOLMAN MICHELL



Consult us at the design stage . . .
we may have an extrusion for that awkward shaped part, or we will know the reason why and quickly make one. Rounds, squares, hexagons are available in stock, ready for delivery by our own transport.

We also manufacture lead sheet and pipe.

HOLMAN, MICHELL & CO. LTD.

Cornwall Works, St. Helens, Lancs.

Tel.: St. Helens 4201-5

Branches at—Wakefield, Birmingham and Glasgow

MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Air Bearings

THE CHOICE of materials and lubricants for bearings and journals may soon for many applications be ameliorated by the introduction of air bearings. Experiments and investigations have been carried out for some time on both pressurised and hydrodynamic-type bearings, the former using air under a relatively low pressure and the latter following the hydrodynamic theory of lubrication. While problems such as eccentricity, non-circularity, surface finish and elastic deformations due either to loading or thermal stresses still exist, the overall problem with hydrostatic bearings is greatly simplified, since the bearing is self-aspirated from its surroundings without the use of additional equipment. In view of the low loading value of 1 p.s.i. per 1,000 r.p.m. it is obvious that these bearings will be used to the best advantage at high speeds, although a dynamometer has been modified by the Mechanical Engineering Research Laboratory to use air bearings, and is sensitive to the weight of a sixpence placed on the balance arm.

As in most new applications, investigations to correlate theoretical predictions with experimental results form a large proportion of the work carried out. In this connection a recent paper for discussion at the lubrication group of the Institute of Mechanical Engineers is of interest, since it investigates pressurised air-lubricated bearings for high-speed shafts. These bearings, with a high degree of surface finish, circularity and parallelism, were tested with radial clearances ranging from 0·001 in. to 0·0006 in. The sizes and geometric arrangement of the pressure jet orifices and the appropriate pressures for each position relative to the journal load are also included in the paper, and many curves illustrate the frictional losses relative to loads, inlet pressures and radial clearances.

Plastics for Bearings

A DEVELOPMENT of growing importance and one which is likely to be of use in several branches of engineering is the use of plastics for ball and roller bearings. Some advantages claimed are a reduction in noise level and excellent resistance to corrosion, but one of the most interesting features is their excellent performance under dirty conditions.

When plastics balls are used in steel races it has been noticed that the bearings are unaffected by grit and this may be of importance for applications where bearing seals are troublesome. Many plastics have been tried out, but phenolic and melamine resins (unfilled) appear to be among the most promising. Applications include domestic appliances where quiet operation is desirable; submersible equipment, where corrosion resistance is necessary; in instruments requiring non-magnetic and lightweight bearings; electrical switchgear where high shock resistance is needed.

Chromium Developments

IN THE SEARCH for materials which have high strength, resistance to creep and fatigue at elevated temperatures with a minimum of corrosion, chromium is receiving a great deal of attention in many parts of the world.

Pure chromium in its annealed form has a tensile strength of approximately 41,000 p.s.i. at room temperature, but it is usually extremely brittle; it becomes more ductile with increase in temperature and by the use of special methods of working. At 1,070 deg. C. it is quite ductile, but it still has an ultimate tensile strength of 9,000 p.s.i. The strength at these temperatures and its resistance to creep can be greatly improved by alloying and its resistance to oxidation and thermal shock is very good indeed. By virtue of its highly reactive nature in the molten state, chromium is likely to remain expensive both as a wrought metal or as a finished product.

To increase its ductility at room temperatures and therefore the ease of manufacture, considerable effort is being expended in a search for suitable alloying agents. Foremost in this is the Fulmer Research Institute at Stoke Poges, which has first-class facilities and personnel and is equipped for helping with works problems, as well as for long-term fundamental research.

New Finishes for Zinc Die-castings

MARKED IMPROVEMENT in the corrosion performance of electro-plated zinc die-castings has resulted from recent research sponsored by the American Zinc Institute and conducted at Battelle Memorial Institute, Ohio.

Two new plating systems investigated during this research programme appear to be particularly useful, and, in fact, are already being used by industry for plating some motor car external trim. One is a composite copper-nickel-chromium system. In this, chromium as thin as 0·000025 in. is deposited in a crack-free and pore-free coating. This plate is applied over the customary thickness of copper and nickel and is said to provide excellent protection against corrosion.

The second is the duplex nickel system. This consists of two layers of nickel electro-deposited in different baths. Conditions for plating the first, thicker layer are adjusted to deposit nickel that is relatively passive to corrosive environments and the outer layer is plated under conditions for depositing bright nickel that requires no buffing. Such nickel is more active chemically than dull or semi-bright nickel plate. Investigations show, however, that the duplex system furnishes much more corrosion protection than an equal thickness of a single bright nickel layer.

Light Alloy Corrosion Problem

THE USE OF MORE LIGHT METALS in motor-car engines and cooling systems will, it seems, pose new anti-freeze corrosion problems for the industry.

Mr. Leonard Rowe, of General Motors' research laboratories, has pointed out that either chemical manufacturers will be prepared to provide materials which are effective in a light metal cooling system or alternative methods of cooling must be found.

Anti-freezes and rust inhibitors that successfully prevent corrosion in present car engines and cooling systems may not solve the problem in aluminium units.

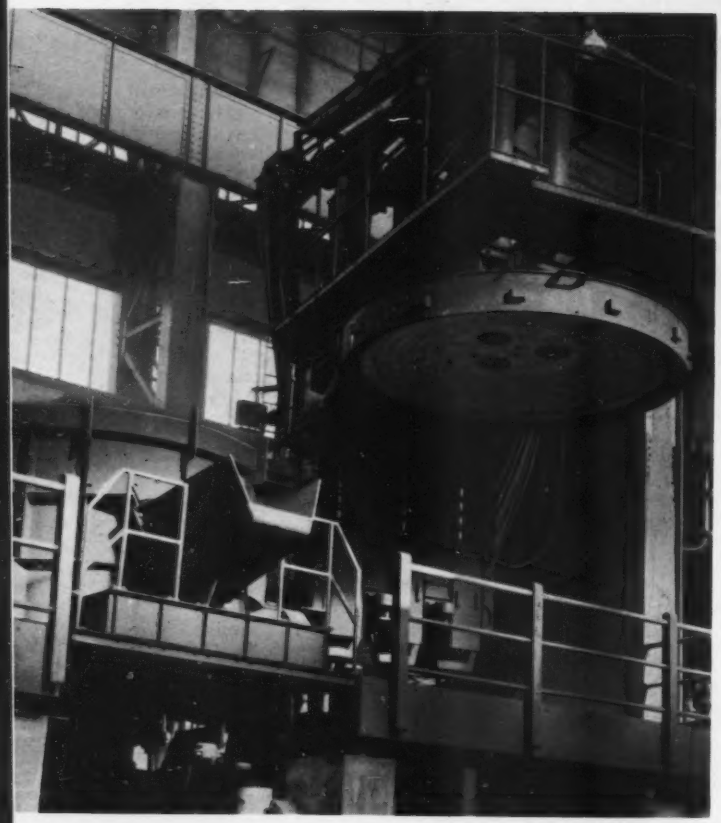
"Regardless of how extensively aluminium is used, it will result in corrosion problems which are slightly different in nature than those previously experienced, for pitting and galvanic corrosion are sure to be more prominent."

Mr. Rowe suggested that chemical manufacturers begin research work to study: (1) effect of water quality on corrosion and inhibition; (2) effect of heat transfer on metal corrosion; (3) effect of surface boiling and hot spots on metal corrosion; (4) effectiveness of inhibition in crevices and low-velocity coolant areas; and (5) effect on corrosion of service variables such as poor maintenance and anti-freeze re-use.

Already, the U.S. motor industry is investigating some of these factors, but if corrosion-free service is to be provided in future engine design immediate steps are needed to prepare for the greater use of light alloys.

PICTURE NEWS

IN THE WORLD OF MATERIALS & DESIGN



SURGE VESSEL

This spherical surge vessel, produced by Marston Excelsior Ltd. for the U.K. Atomic Energy Authority, is 14 ft. in diameter, and was fabricated from light alloy pressed segments ¾ in. thick.

ARC FURNACE

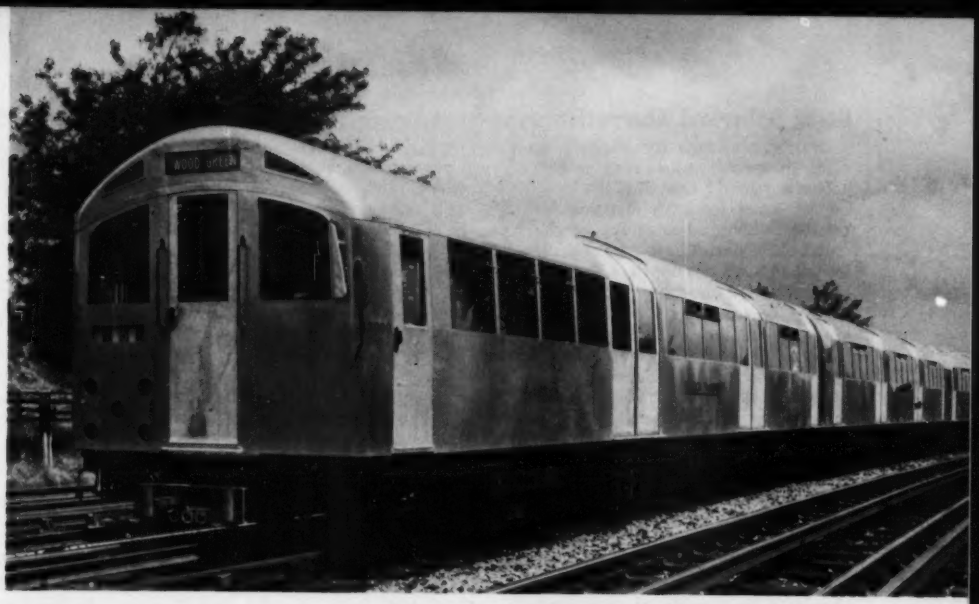
This three-electrode, six-ton capacity arc furnace is installed at the new research station of the French Iron and Steel Institute in Moselle. The furnace is hydraulically operated and has a pivoting lid. It can melt four tons of pig iron in little over an hour.

ALUMINIUM CAR

This Kaiser scale model of a car is an all-aluminium design. Body panels are stamped sheet with enamelled finish, with side trim of brushed and gold-colour anodised aluminium. Bumpers, roof rails and top roof panel are all of aluminium.

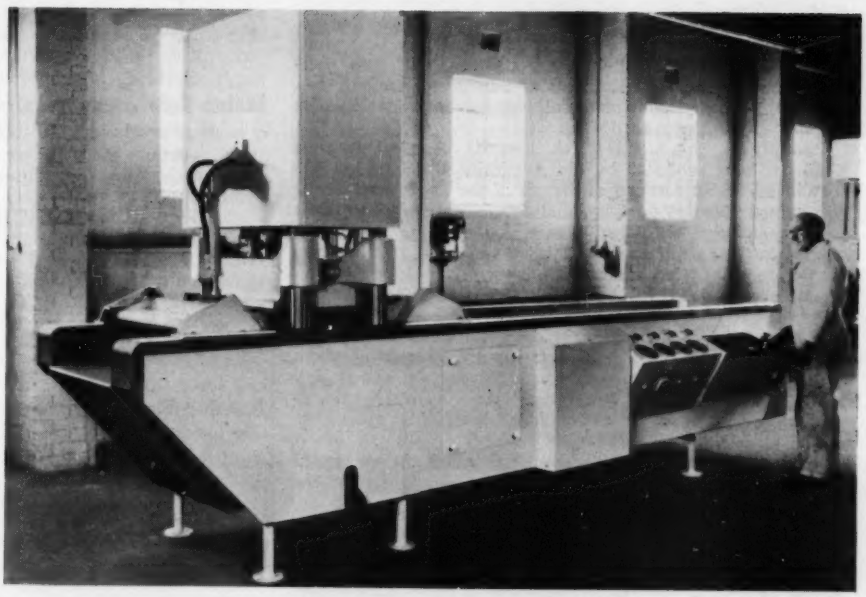
ALUMINIUM ON THE TUBE

These unpainted aluminium trains are being progressively introduced on the London underground system. Light alloy bodies save (1) weight, and thus energy consumption; (2) about 4 cwt. of paint per car; and (3) cleaning and maintenance costs. Rubber is used for the bogie bolster and axlebox suspension.



CONVEYOR PRESS

(Centre right). Developed originally for extracting protein from green leaves, this automatic conveyor press by Modern Mechanisation Ltd. is capable of expressing water, oils or juices from a variety of granular or fibrous materials. Parts in contact with products are stainless or chromium steel, rubber or woven synthetic fabric.

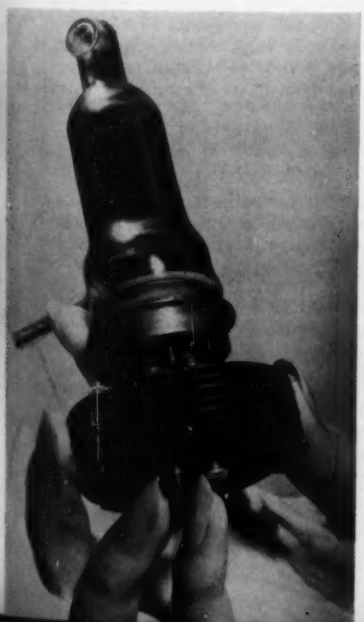


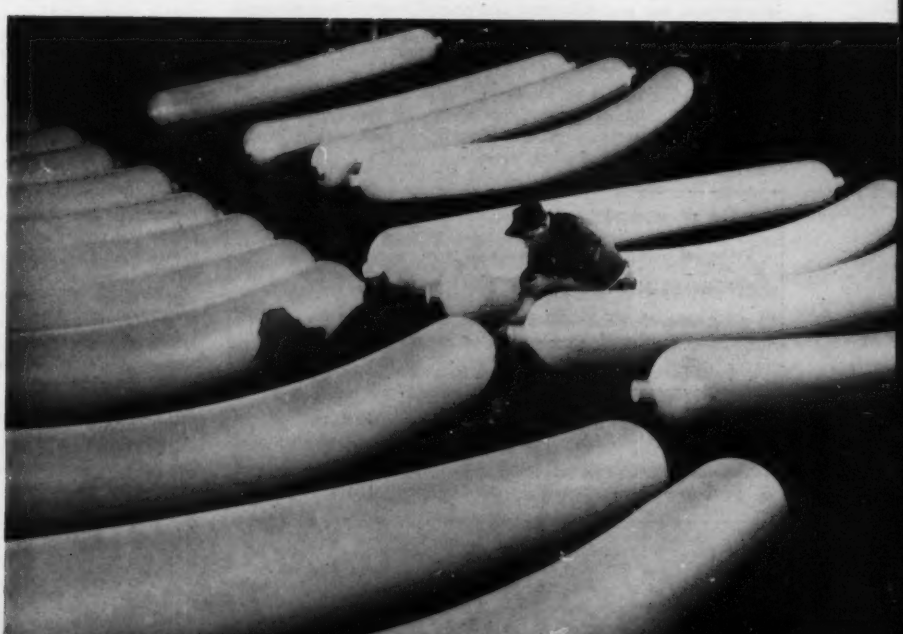
PHOTODETECTOR

(Below left). In this Nortronics photodetector a two-stage Peltier cooler and a photoconductive cell are enclosed in an evacuated glass envelope. Cell is mounted at tip of first-stage cold finger and is centred in the field of view of a sapphire window. Useful cooling range is approx. 40 deg. C. below ambient of 25 deg. C.

OXYGEN CYLINDERS

(Below right). Shaped to fit the curve of a submarine hull, these oxygen cylinders are constructed of seamless steel. The American Iron & Steel Institute's magazine, Steelways, reports that twenty-two nuclear submarines are now afloat or projected in the U.S.A.





Using Spherical Aberration

OPTICAL METHODS for aligning machines and equipment are often of special value, since a line of sight represents a very accurate straight line. But the usual alignment telescope must be refocused for each distance, so that its accuracy depends on the mechanical accuracy of the focusing adjustment

Recently, Dr. J. H. McLeod, of the Eastman Kodak Co. in the U.S.A., developed a lens with a conical surface called an axicon. It directs rays from a very small source of light so that an image of the source can be obtained at any point along a straight line without refocusing.

Conical surfaces are difficult to produce. Dr. W. H. Steel, of the Commonwealth Scientific and Industrial Research Organisation in Australia, has now designed axicons with easily-made spherical surfaces. In the design of a conventional lens great care is taken to correct a defect known as spherical aberration. By making lenses with a large amount of aberration Dr. Steel has produced "lens axicons". With suitable light sources, these give high-precision alignment over distances up to several hundred feet.

Axicons can be used also to set up equipment exactly at right angles to a line. An "axicon autocollimator" for aligning and squaring-on has been made in the organisation and shown to be capable of very accurate performance.

Silicon Nitride

ENGINEERING DESIGN frequently demands materials which possess good mechanical strength, stability, oxidation resistance, thermal shock resistance and ductility at temperatures up to 1,200 deg. C. No material has yet been found which satisfies all of these conditions.

Recently, a compound which has the chemical formula Si_3N_4 has been produced by the Admiralty Materials Laboratory in a suitable form to satisfy all of the above engineering requirements except ductility, and this is being overcome by suitable attention to design criteria.

Experimental application of this new material is proceeding for gas-turbine guide vanes, high-temperature electrical insulators, combustion chambers, crucibles and refractory supports.

The material is light grey in colour, has an average apparent density of 2·2, a transverse rupture strength of about 7 t.s.i. at room temperature and at 1,200 deg. C., and is very hard. It can be produced to intricate shapes by powder metallurgy techniques, or by conventional machining operations, and is reasonably cheap.

It is unattacked by most common chemicals, is not wetted by molten metals and should have wide application in the future.

Nylon Guides for Underground Lifts

ONE OF THE ORIGINAL LIFTS in use in 1900 when the first section of what is now the Central Line of the London underground system was opened has recently been brought back into service, but reconditioned and re-equipped to use materials that were not available when they were first built.

The use of nylon liners in the car guide shoes in place of the bronze liners originally fitted has enabled grease lubrication of the guides to be abandoned and has shown great advantages in reducing wear. The pivots of the levers in the door-operating mechanism are also fitted with nylon bushes with the object of reducing wear.

IN NEXT MONTH'S ISSUE . . .

Principal features in the March issue of

ENGINEERING MATERIALS AND DESIGN will include:

Resin-bonded Fabric Bearings
Their increasing potential for many engineering uses.

Palladium in High-temperature Brazing
Advantages of its use in certain filler alloys.

Design Factors in the Selection of Springs
Specification for compression and extension springs.

Growing Uses for Beryllium
Current development in the U.K. and abroad.

Titanium Heat Coils in Chrome Vats

THE USUAL METHOD of heating chrome-plating vats by means of an external jacket carrying hot water or steam is expensive in capital and maintenance costs, the latter being awkward because leakage of plating solution is difficult to detect. Furthermore, control of vat temperature is complicated by the high thermal capacity of the jacket.

A more convenient way of keeping the solution at working temperature is to immerse a steam heating coil in the vat, but conventional materials give poor service owing to chemical attack often accompanied by mechanical damage. Coils made from titanium tubing, which is available in a variety of diameters and gauges, overcome these problems. Titanium is completely inert to chromic acid hot or cold, and steam coils with a wall thickness of the order of 20 s.w.g. will last indefinitely. It is reported that vats can be heated with titanium coils in 25 per cent less time than with lead coils of the same size.

The strength and lightness of titanium make simpler designs possible, as supporting struts are usually unnecessary and a titanium coil weighing only 5 or 6 lb. has the same heat transfer capacity as a lead coil weighing about a hundredweight. Although titanium is a more expensive material, because it is easy to fabricate and because the components can be made many times lighter than in lead, in actual practice a titanium steam coil for a given duty costs little more than a lead one and lasts much longer in service.

Metal Reinforces Plastics

CAST EPOXY RESINS for the manufacture of metal-forming tools, such as press dies, are now being reinforced with steel or aluminium fibres. Inclusion of metal fibres has resulted in greatly-improved impact strength and resistance to wear. Heat conductivity is enormously improved and the tools can be made magnetic. The easy machining of metal fibre-reinforced resin compared to steel, as well as the fact that many shapes can be moulded direct off a prototype, means that considerable economies can be made in die costs. The new reinforced resins have proved to be satisfactory for short and medium production runs.

Powder Metal Development

A MILESTONE in the field of powder metallurgy—the development of a high-strength, low-alloy iron powder—has been achieved by Republic Steel Corporation.

The new iron powder, called type 6460, incorporating small quantities of nickel and molybdenum as alloys, opens the way to countless new applications of powder metallurgy. Previously, iron powder was regarded as suitable only for parts subject to low stresses. With this new powder, minimum tensile strengths of 60,000 p.s.i. as sintered, and 100,000 p.s.i. when heat treated, can be developed.

Fabrication of parts permits normal briquetting pressures and normal sintering cycles followed by normal heat treating procedures. Also, the dimensional characteristics after sintering fall within the commonly-accepted tolerances of the powdered metal industry (maximum 0·004 in. shrinkage from die size at 6·4 density).

New Phosphors

INTERESTING new developments in the production of phosphors for cathode ray tubes reported by Ferranti Ltd. include a range of phosphors whose luminescence is only visible when infra-red radiation of particular frequencies is directed on to them. Since the phosphors are selective in their response to infra-red of different wavelengths it is possible by switching infra-red sources of different wavelengths to obtain a succession of different images on a radar or TV screen.

The development is of special importance for radar where it will enable an image to be stored and remembered for periods up to twenty minutes. Thus it should be possible to record the tracks of several ships or aircraft and recall them at will or fade them out as required. Because the new phosphors are activated by infra-red sources, the problem of visible afterglow is eliminated.

Engineering Materials and Design

ARE NICKEL SUPPLIES ASSURED?

"CONSUMERS can be assured of steady, abundant supplies of this extremely useful metal in the years ahead." This statement was recently made by Dr. John F. Thompson, chairman of the board of the International Nickel Co. of Canada Ltd., in a review of the nickel industry in 1958. Nickel is one of the most important raw materials for the engineering industry and for many applications it is indispensable. It is interesting to note that in 1958 approximately forty-four per cent of the free world nickel was used by the steel industries for stainless and alloy steels. Stainless steel is continuing to find many new uses in engineering where its resistance to corrosion and heat, coupled with its excellent mechanical properties, have enabled it to compete with mild steel and light alloys which frequently require elaborate protective treatments.

Free availability of nickel has made it possible for alloy steel consumers to return to the higher nickel-containing types for established applications such as in automobiles, trucks, tractors, aircraft, military equipment, farm machinery and road building and transportation equipment. An example of the use of nickel alloys in transportation is in the modernisation programme of the British Railways, where nickel-chromium case-hardening alloy steel is being employed for diesel locomotive roller bearings. An ultra high-strength nickel-containing alloy steel is being used in increasing quantities for landing gear components of new jet transport aircraft, as well as in sheet form for various parts of missiles. The most important new applications are those involving heat-treated, high-strength structural plates and shapes containing up to about three per cent nickel for bridges, pressure vessels and hulls for naval vessels. Alloy steels are also being specified for low-temperature service.

The high-nickel precipitation-hardened and other related alloys provide the strongest cast and wrought compositions commercially available for such highly stressed items as turbo-jet rotor blades for operation at elevated temperatures, and these alloys are specified for most of the first-stage jet engine turbine blades. In the more advanced propulsion systems, high-nickel alloys are especially well suited to resist the corrosive action of the new boron-containing high-energy fuels.

The periodical nickel shortages which have occurred during the past twenty years have resulted in the curtailment of supplies for many uses where this metal is not absolutely vital, such as in the electro-plating field. Attempts to replace nickel for such applications have been actively carried out for many years but, except for one or two relatively minor developments, there has never been produced a really satisfactory substitute. It is unfortunate that in many products such as motor-cars, the last twenty years has seen a noticeable drop in the quality of chromium plating as a protective coating for steel; this has often been blamed on the shortage of nickel, although the reduced standards of quality which seem to have now become accepted may be retained for economic reasons.

Many changes have taken place in the requirements of the engineering industry since before the last war, but developments involving large quantities of nickel have not been so thoroughly pursued as might have been the case if it had been freely available. Nickel-cadmium batteries, for instance, have been the subject of remarkable technical developments in recent years with the advent of the sintered plate, but manufacturing capacity and commercial exploitation of the battery do not seem to have advanced as much as would have been expected.

Manufacturers who have had to manage without nickel or who accepted reduced supplies will undoubtedly return to it willingly if they have not already done so, but a more important problem will be the question of whether to develop or extend manufacturing facilities for new nickel alloys or products. Where much capital expenditure is involved, and possibly new sales organisations required, there will be some feeling that the immediate past history of nickel does not inspire confidence for the future.

It is therefore worth examining the factors which have led to Dr. Thompson's statement and to try to understand the dramatic changes which have taken place in the nickel industry. The total nickel consumption in the free world during 1958 was expected to be approximately 330,000,000 lb., about twenty per cent down on the previous year. On the other hand the production of nickel for 1958 was estimated at about 525,000,000 lb., almost double the capacity existing prior to the Korean conflict. Nickel production capacity is expected to rise progressively in the next few years to a figure of about 650,000,000 lb. in 1961 and this is approximately double the consumption for 1958. Furthermore, the U.S. Government has authorised the diversion to industry of well over 100,000,000 lb. each for this year and next. In view of these figures, it is clear that as far as it is possible to forecast there will be ample supplies of nickel for civilian and military purposes for many years to come and, therefore, engineering designers can specify the use of nickel and its alloys for the many purposes where it is the best and simplest solution to their design problems.

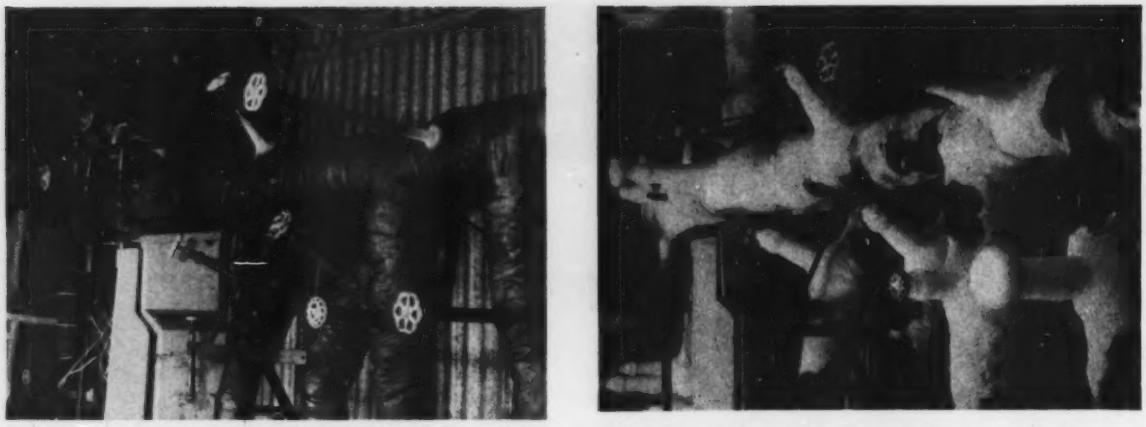


Fig. 1. *Left.* Example of efficiently-insulated assembly operating at —180 deg. C. approximately. *Right.* The same test facility operating under identical conditions, but badly insulated.

ENGINEERING PROBLEMS ASSOCIATED WITH LOW TEMPERATURES

Increasing applications of low-temperature fluids raise specific problems in the design of handling equipment and materials used in its construction. This article outlines some of the factors involved

by D. H. TANTAM, A.M.I.Mech.E.*

THE engineering problems arising from the operation of equipment at sub-zero temperatures vary in magnitude with the level of temperature. Although the temperature span from ambient to absolute zero is some 300 deg. C. only, this reduction in temperature has a profound effect on the behaviour of materials.

The properties which are of the most interest to the engineer are tensile strength, impact value, thermal conductivity, coefficient of thermal expansion and workability. These properties are important in the selection of the materials to be used, but much can be achieved by design to avoid subjecting parts of the equipment to the extremes of low temperature and thereby permit the use of cheaper materials. In instances where this is not possible, it may be necessary to develop new materials or employ combinations of metals and non-metals to meet the desired duty.

Superimposed on these points of design are those arising from environment where not only corrosion must be considered but also obstructions due to the freezing of atmospheric water vapour and other impurities and the liquefying of the constituents of the air itself.

How far these factors influence the design and operation of equipment can best be seen by arbitrarily subdividing into groups the span of temperature from freezing point to absolute zero. For the purpose of this general treatment of the subject, these groups are identified by practical applications. It is intended, however, to study the engineering problems arising from low temperature only, and no consideration is given to the problems associated with the process itself.

* *Engineering manager, British Oxygen Research & Development Ltd.*

Domestic or Climatic : Ambient to —30 deg. C.

In this region the principal difficulties arise from the formation of water ice, although a marked reduction in impact value of some materials takes place. It is evident from Table 1 that the impact value of mild steel is markedly reduced and that the resilience properties of rubber are similarly affected. The small amounts by which these materials are affected does not preclude their use, but account must be taken of these facts when designing the equipment. Furthermore, where dissimilar materials comprise an assembly, additional stresses will be introduced due to differential contraction. But at these temperatures it is probable that the strength of the material is adequate to accommodate the small extra load. It is, however, likely that if sweated joints are exposed to such stresses, leaks may develop and consideration must be given in the layout of the interconnecting pipework to ensure suitable flexibility of bends or similar methods. Such a system is preferable to the introduction of expansion devices, which may in themselves introduce further maintenance.

Frost or ice formation resulting from the freezing of atmospheric water vapour is the main cause of operational inefficiencies, not only from fouling the heat-transfer surfaces but also impairing the function of components where relative movement occurs. Although frost is friable and will break off under its own weight or due to vibration, ice which is formed from free moisture, either during the thawing frost or the impingement of water, is more tenacious and can seldom be removed other than by thawing. In these circumstances it is customary to maintain the parts of the equipment which would be affected at temperatures above freezing point by introducing a

temperature gradient between it and the low-temperature components. Such a heat-transfer resistance may be achieved by insulation or the addition of heat such as that generated in glands or bearings.

Where continuous operation is essential, the equipment is sealed in its own atmosphere, which may be air or gas suitably dried or purified. In such instances it is important to consider the behaviour of the materials under moisture-free conditions, when in some cases an increase in wear rate results. One such material is carbon. Attention must also be given to the dissipation of heat, and adequate cooling surfaces must be provided.

The condensing of free moisture on the cold surfaces accelerates corrosion unless due regard is paid to the galvanic potential in the selection of the materials and also the mass relationship of the items forming the assembly.

TABLE 1. Mechanical properties of materials at low temperatures

Material		Temp. °C.	Proof stress (0·2%) tons/in.²	U.T.S. tons/in.²	Elongation % on 2 in. G.L.	Izod impact value ft. lb.
Aluminium (99·88% pure) annealed		Room	2·03	4·06	51	19
		− 10	1·79	5·10	35·9	—
		− 40	1·78	5·20	39·8	19
		− 80	1·96	5·30	37·9	20
		−120	1·58	6·30	39·5	21
		−186	2·03	9·30	43·8	27
Copper annealed (99·98% pure)		Room	3·5	14·7	52·0	43
		− 10	3·97	14·3	40·2	—
		− 40	4·09	15·1	47·0	45
		− 80	4·50	17·2	47·0	44
		−120	4·82	18·4	44·6	44·5
		−180	5·12	22·7	57·6	50·0
Brass (70/30) annealed		Room	15·9	24·2	58·0	65
		− 10	12·8	23·7	48·5	—
		− 40	12·0	24·4	57·7	66
		− 80	12·2	25·5	59·5	67
		−120	12·5	27·3	54·7	71
		−180	13·2	32·8	74·6	79
Austenitic stainless steel 18/10		Room	16·5	41·4	54·0	
		− 20	19·0	51·0	62·5	All unbroken with not less than 100 ft. lb. absorbed.
		− 60	22·2	61·1	61·0	
		− 96	24·0	69·0	46·1	
		−116	32·5	80·0	48·5	
		−180	33·3	99·5	45·7	
Mild steel	Carbon 0·08%	Room	22·3	30·4	31	52
		− 32	—	—	—	44
		− 46	—	—	—	2
		−162	35·9	42·4	39	—
		−184	40·4	48·9	17	—
		−196	46·4	51·8	3	—
	Carbon 0·13%	Room	24·4	29·6	29·7	81
		0	—	—	—	65
		− 40	—	—	—	41
		− 65	30·2	36·0	33·6	21
		− 90	—	—	—	2
		−180	—	54·2	26·5	—
	Carbon 0·22%	Room	23·7	32·8	29	69
		0	—	—	—	58
		− 19	—	—	—	36
		− 55	—	—	—	23
		− 81	—	—	—	13
		−162	37·5	47·3	—	4
		−184	37·5	51·6	9	3
		−196	49·6	54·9	6	—

TABLE 2. Thermal conductivity of metals

Material	Conductivity c.g.s. units	
	At —160°C.	At room temp.
Aluminium	0.514	0.504
Copper	1.097	0·918
Brass 70/30	0·181	0·260
Steel	0·113	0·115
Stainless steel	—	0·038

TABLE 3. Resilient properties of non-metals at low temperatures

Material	Minimum operating temp.
Butyl	—50°C.
Vulcanised rubber	—15°C.
Neoprene	—35°C.
Silicone rubber	—80°C.

Deep Freeze: —30 deg. C. to —100 deg. C.

With this further reduction in temperature, the effect on physical properties of some materials is so marked as to restrict their application. The loss of ductility may more than offset the gain in tensile strength. An improvement in these properties can be obtained from the use of alloys and heat treatment of the raw material or the finished article.

At times when the consideration of costs or production methods make it attractive to avoid taking these steps, the component should be safeguarded against impact or shock loads or high acceleration forces. For the most part, this will impose restrictions on the method of operation such as length of cooling-down time or conditions under which the equipment may be used.

Difficulties arising from lubrication begin to assert themselves at this temperature, and mineral oil lubricants in particular suffer from increase in viscosity and even exceed their pour point. Fully-flooded lubrication gives way to boundary lubrication where the heat generated between the lubricated surfaces is sufficient to maintain the level of temperature at which the oil is able to function. Certain materials which are flexible at near ambient temperature lose that property at this reduced temperature level and, as will be seen from Table 3, vulcanised rubber gives way to synthetic rubbers, such as Neoprene. Silicone rubber exhibits the best low-temperature resilient properties.

Liquefied Gases: —100 deg. C. to —200 deg. C.

In this region the use of many materials are precluded on the grounds of loss of ductility and the resulting low-impact value. This obstacle may be overcome either by design or choice of materials or a combination of both.

DESIGN—It is not possible, as in the previous two groups, to rely on locally-generated heat to maintain the temperature of moving components above freezing point, and better use must therefore be made of the abundant atmospheric heat which is available. Alternatively, forced heat systems and their running costs will be involved. At the same time it is necessary to avoid introducing considerable heat into the low-temperature process where cold losses are a disadvantage. It is therefore necessary to insert a heat break or resistance such that a temperature gradient will be established between ambient and these low temperatures.

Losses due to conduction can be reduced by paying attention to (1) conductivity of the material; (2) cross-sectional area; and (3) length of flow path. For example, a low-temperature valve is shown in Fig. 2 in which the gland is maintained remote from the process fluid by a low heat-transfer extension. In this case austenitic stainless steel of the 18/8 grade is a good material to use because of its strength at low temperature and its low thermal conductivity (see Table 1). This way, a small cross-sectional area can be employed for both spindle and gland housing extension. In order to establish the frost line away from the gland, under equilibrium conditions the extension must be unlagged although the process fluid-bearing components must, of course, remain lagged to reduce cold losses. To maintain the temperature difference, however, it is obvious that the process fluid itself must not have access to the part it is required to thermally insulate, and a stagnant gas pocket is established between the fluid and the gland by siting the gland above the fluid level or otherwise restricting the convective or gravitational circulation of the liquid in the valve extension.

MATERIALS—Metallurgy yields the information which is necessary for deducing the properties of a material with change in temperature. The plastic properties of metals are determined by the lattice structure, and its

influence controls those properties of coefficient of thermal contraction, thermal and electrical conductivity, tensile strength, workability. Metals with certain lattice structures exhibit good plastic properties independent of reduction in temperature. Among these are nickel, aluminium, copper and the noble metals. On the other hand, the lattice structure exemplified by carbon steels has poor plastic properties, even with small reductions in temperature. Yet another form of lattice exhibits properties somewhere between these and, as in the case of zinc and magnesium, retains its ductility with reduction in temperature but loses workability.

It is well known that by alloying these materials a disturbance in the lattice structure results and improvement in low-temperature properties can be obtained. It is often the case with some alloys that the improvement in ductility is at the expense of workability and care must be taken during manufacture, or even production of the raw material, to avoid cracks which will later lead to notch effects, resulting in brittle fracture of the material. It is therefore not possible to use these materials in the fabrication of components where final heat-treating cannot be carried out.

This is also true in the case of some non-ferrous materials, for instance, aluminium, where it is attractive to use the higher strength for weight alloys which, however, have the disadvantage of requiring heat treatment. In certain cases, where heat treatment cannot be effected, the binary alloys of magnesium and aluminium are employed.

Broadly speaking, it may be said that copper and bronze, aluminium and austenitic stainless steel are the most commonly used metals and their selection for low-temperature uses is determined by their merits and economic attraction under the conditions for which they are applied.

The selection of the correct material alone is not enough to ensure the success in application of a vessel at low temperatures. Particular attention must be paid to stress raisers arising from porosity in cast materials or welds, discontinuity of sections and hair cracks in material from holes or other such points as a result of machining or thermal stresses during fabrication.

Consideration must be given in the layout of a system or the design of a component to avoid crippling or buckling stresses of members which are in compression or alternatively failure in tension due to inadequate provision for support, flexibility and alignment. This is particularly important in installations where the cooling-down period is extremely short and high point stresses are introduced due to localised cooling.

Too much importance can, however, be attached to notch impact strength of materials and at times a material with poor properties in this respect can be used quite safely in places where a high rate of loading will not occur.

LUBRICATION—In those cases where relative movement of parts takes place lubrication is necessary and this presents difficulties at low temperatures, particularly where an inflammability hazard exists due to the process material being handled. Most lubricants lose their lubricating properties at very low temperatures and in many cases are no longer fluid unless locally generated heat due to friction can maintain the temperature at the point of lubrication above the pour point of the lubricant. Where the lubricant is used merely to stop binding, such as on screw threads, molybdenum disulphide or similar lubricants can be employed, but for positions where the lubricant not only reduces friction but also acts as a coolant between the bearing surfaces, greater problems exist. The inherent low coefficient of friction of some non-metals are exploited to the full in this connection, but it is not unusual to find, however, that these materials suffer from other defects which must be overcome or otherwise rendered ineffective in their application at low-temperature uses.

For instance, p.t.f.e. has low coefficient of friction properties which are maintained at low temperatures, but, un-

Fig. 2. Unlagged equipment, showing ice formation. Note low-temperature valve.

Fig. 3. Mechanical rotating shaft seal at —180 deg. C. approx.

fortunately, it also has an exceptionally-high coefficient of expansion, poor thermal conductivity and poor dimensional stability. It is therefore necessary to employ this material in such a way that its merits may be used to advantage without incurring the undesirable features. The dispersion of p.t.f.e. in other materials, such as impregnated bronzes, are one approach to this problem, but this is a first step only in establishing a suitable bearing where each application must be considered from the point of view of clearances, bearing loading and surface finish.

The same factors play an important part in the use of other non-metals in these applications, and in the case of carbon the problem is made even more difficult by the variation in composition of the material itself.

Despite the use of these materials with low coefficient of friction, it is still necessary to provide a means of conducting the heat from the frictional interface. In most cases the conduction through the bearing or shaft themselves is not adequate and the process fluid in the absence of other lubricants must act as coolant. In this respect, where liquefied gases are being handled steps must be taken to ensure that the passage of liquid through the bearing is not interrupted by the formation of gas pockets or other vapour locks. The passage of water ice or other such obstructions through the fine clearances would cause damage if not catastrophic failure, and for this purpose fine filters are introduced in handling systems where such hazards exist.

This is particularly true in the case of ball and roller bearings, where the clearances are very fine. It has been established, for instance, that the clearances between the cage and the balls where the sliding friction is greatest are vital to the life of the ball race, and to this end composite ball races have been developed for use at low temperatures, where the components of the race comprise metals and non-metals.

FLEXIBILITY—Most flexible materials at ambient temperature lose their resilience at the temperatures of liquefied gases, and it is often necessary to turn to man-made fibres, woven into cloths or similar forms to give the flexibility desired in such items as diaphragms. It is better, however, to use metals where possible, as this assists greatly in making an impervious assembly and a sealed joint under pressure. Since the joints are the weakest part of the assembly, it is not surprising that preference is given to the use of metals where convolutions or similar techniques are used to obtain the required flexibility. Flexible hoses for the transfer of liquefied gases are usually made from copper or stainless-steel convoluted hose with bronze end fixings welded to the hose itself. Where non-metals are used, the joint to the end fixings is difficult to achieve and at the same time the bore must be lined to prevent leakage through the walls of the tube.

In cases where resilience only is required, such as gland packings or jointing materials for flanges, this is obtained by the choice of suitable materials whose elastic properties are maintained even at low temperatures. Asbestos is a material which is used to good effect in both these applications and maintains its resilience although much reduced at the low temperatures, and this property is restored without ill effect when thawing to ambient conditions. The use of suitable bonding materials and filling materials vary with the application of the asbestos, but conform approximately to the practice followed in the selecting of these materials for duties at ambient temperatures. Attention must, however, be given in selecting the bonding material to ensure that it is not hygroscopic, as subsequent freezing with reduction in temperature will break up the asbestos material.

JOINTS—In the case of gaskets for flanges the material must be deformed to make a seal between the mating faces, and the essential factors in a successful joint are the relationship of contraction with the temperature gradient across the components which comprise the assembly. Unless due consideration to these points is given, the bolts will be over-stressed during the cooling down, or alternatively will become slack and will cause the joint to leak. Continual over-tightening of the joint components will inevitably lead to leakage and in some cases complete failure of the joint. Considerations arising from pressure and other stresses of the application conform to the practice for flanges at ambient temperature. The initial bolt stress is in some cases of paramount importance, and on site it will be necessary for these joints to be tightened with the use of a torque spanner under ambient conditions so that the stresses under low-temperature conditions where these are the most arduous will be controlled.

Metal-to-metal face joints usually employed for high pressures or similar lapped seating faces will in certain materials require stress-relieving to avoid distortion across the sealing face due to reduction in temperature. This difficulty also arises in mechanisms where small clearances are to be maintained and changes in alignment of components have resulted from the addition of the thermal stresses to the residual stresses already existing in the components causing distortion in the material.

Where proprietary brands of joint are employed using novel methods of sealing to the pipe wall, it is not only essential in the case of low temperature uses that the joint should be properly made but also that the design must be such that dimensional change due to reduction in temperature makes the joint tighter.

INSULATION—To conserve the energy of the system it is necessary to insulate against the ingress of heat from the atmosphere or environment. A method has already been described by which the temperature gradient is established between the atmosphere and the process fluid by means of selection and use of materials to prevent conduction and convection losses. The bulk of the insulation on a plant, however, is obtained by lagging external surfaces. Not only must consideration be given to the usual requirements of thickness and type of insulation but also sealing against ingress of atmospheric water vapour upon cooling the air within the lagging.

Where high-efficiency insulation is required, vacuum is used and due emphasis should be placed on the design of the vessel that the joints and material specification is commensurate with the vacuum to be maintained. Owing to the arduous conditions imposed by the use of highly reflective surfaces in an unfilled high vacuum, it is now commonplace in large-scale installations for the transport of liquefied gases to employ powder-filled vacuum systems.

Ultra Low Temperatures (Near Absolute Zero)

Equipment built to handle such material as liquid hydrogen, 20 deg. K., and liquid helium, 4 deg. K., have certain components operating at these temperatures. This is obviously a specialised field of engineering, and not only are the difficulties enumerated earlier increased considerably but many materials are ruled out altogether. In some cases a remarkable change in behaviour occurs and this applies particularly at the very low temperatures, where thermal conductivity and electrical conductivity are particularly affected.

A great deal of investigation is proceeding into the behaviour of materials at these low temperatures, but it is permissible only to report generally on the problems encountered.

The increased differential contract between different parts of the apparatus increase the difficulty of accommo-

dating these dimensional changes. Flexible components are even more difficult to design, and insulation in the form of heat break plays an even more important part.

With the increased temperature difference, more emphasis is placed on heat loss due to radiation. This affects the degree of vacuum and the cleanliness and polish of reflective surfaces in the insulating space. In those components where size permits the use of powder-filled vacuum systems the degree of vacuum is reduced to limits which allow easier manufacture and maintenance of vacuum in practice, but it is necessary to insert radiation shields between the inner and outer walls of the vessel. This generally takes the form of a jacket filled with a liquid boiling at an intermediate temperature and situated between the liquid-containing vessel and the outer wall of the assembly.

It is evident that construction of a vessel of this type is particularly difficult where it may be further necessary to prevent altogether the venting of the material in the inner vessel. It is usual in such circumstances to sacrifice the material comprising the radiation shield. Careful control is necessary not only with regard to the pressure level in the insulating jackets, but also the contents of the radiation shield. Superimposed on this is the efficiency of the safety devices which must be fit to operate under all conditions.

Effect of Properties of Fluids

This survey outlines the engineering problems associated with the design of equipment for low temperature uses. It does not take into account the effect of the properties of the fluids being handled. Their influence affects such properties as corrosion, contamination, inflammability, toxicity, heat transfer and dynamic properties and conditions of state. The influence of these factors must be considered for each particular material being handled, particularly with respect to sealing and insulation of lubricants. In this field liquid oxygen is one of the more common low-temperature materials, which, on the grounds of fire hazard, restricts the choice of material that may be used.

A point which must not be overlooked in the design of low-temperature equipment, where the fluid being handled is present as a liquid and which boils below ambient temperature, is that provision must be made in the pipework system for pressure relief of any section which it is possible to isolate and allow to warm up. If such a precaution is not taken, the increase in pressure resulting from the large volume relationship between gas/liquid will usually result in overstressing the pipework system or associated equipment.

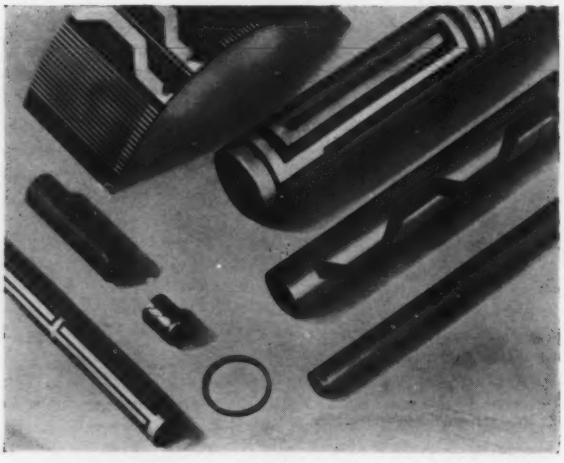
Although each particular plant or equipment designed for low temperatures will have its own problems, the general methods of design described in this article will apply to all systems, and as long as attention is given to these points many of the major difficulties associated with the design of a low-temperature system will have been overcome.

The author would like to thank the directors of British Oxygen Research & Development Ltd. for permission to publish this article.

PRINTED CIRCUITS NOW IN TUBULAR FORM

PRINTED circuitry, for a number of years generally accepted for use in electronics and communications work as well as in instrumentation, has so far been limited to application mainly to flat surfaces. Recently in the U.S.A., however, direct printing of solderable silver circuits on either the exterior, interior or both surfaces of tubes and cylindrical shapes has been achieved by the J. Frank Motson Co.

They provide conductive or resistive electronic circuits without limitations imposed by size, shape or base material. They differ from printed circuitry, as generally understood in the electronics industry, in that the conductive material forming the circuit is applied directly to the base material only where required. The etching process, inherent where copper-clad materials are used in circuitry, is eliminated.



Examples of the range of tubular and other shapes that can be used for direct printing of circuits.

In general, the tubes used for circuitry need to have an inside diameter of ¼ in., but continuous coatings for shielding or conduction have been applied to tubes having an inside diameter as small as 0·020 in. The only limitation on length is the available length of tubing. The circuit can be applied to the inside or outside of tubes, cones, cylinders and other geometrical shapes and where thin or flexible base materials are advantageous. Thermal expansion approximates the thermal expansion of most plastics-based materials.

Almost any type of non-conducting tubular material may be used, including p.t.f.e., epoxy, phenolic, polyester, silicone, glass, ceramic and thermoplastics. The conductive inks are deposited from 0·0004 to 0·0015 in., depending upon requirements. Pattern tolerance can be held under some circumstances to ±0·001 in. The circuits are stable up to 260 deg. C.

Three basic silver inks are used, one of which may be dip- or iron-soldered. They cover end-use temperatures of 260 deg. C., 150 deg. C. or 80 deg. C. Modifications of these basic formulæ make possible inks which meet specific requirements covering an extremely wide range.

The direct-printed tubes have been used as instrument housings, for Faraday shields, capacitance-type fuel gauges, resistors, heaters, probes, commutators, microwave parts, etc.

SEMI-REFLECTING GLASS GIVES INFRA-RED PROTECTION

A BARRIER against infra-red radiation is called for in many industries, particularly in iron and steel production where there is a danger of thermal radiation from furnaces, bloomings, etc. An interesting development in this field is the Polyverbel semi-reflecting glass which is produced by the Belgian company, Union des Verreries Mecaniques.

This has reflecting powers for infra-red radiation by virtue of a coating deposited on one face of a sheet of glass, and, since there is negligible absorption, the temperature of the panel is only slightly raised. To avoid damage to the coating the treated panel is assembled with a protective shee of ordinary glass within the framework of a Polyverbel unit.

Where thermal and mechanical shocks are likely to be encountered it is desirable to use a toughened glass which has a resistance five to six times greater than ordinary glass, although the use of toughened glass does impose a limitation to the size at present available, the largest of which is 48 in. × 36 in. For an assembly of a toughened sheet and one ordinary sheet, a maximum size of 99 in. × 66 in. is possible. To obtain the maximum efficiency against the infra-red radiation, the assembly must be fitted so that the semi-reflecting sheet is facing the source of radiation. Various forms of glazing to suit particular requirements are available, one example being shown in Fig. 3, which indicates how a sheet of ordinary glass and a sheet of the treated glass are separated by dehydrated air and sealed in a frame.

Fig. 1, which gives an indication of the relative specific transmission values of original, athermic and semi-reflecting glass, does not take into account the reflection, since this value is practically identical for every type of glass and is about 4 per cent for each face.

From Fig. 2, which shows the transmission, reflection and absorption of semi-reflecting glass, it will be seen that the quantity of reflected energy increases from the visible towards the infra-red, while the absorbed energy is practically constant. The following table indicates comparative values for different glazing installations with and without semi-reflecting glass used in a varying manner, from which may be seen the importance of correctly positioning the coated glass.

Reflective properties of various types of glass

Type of glazing installation. (Environment at 20 deg. C.)	Thermal transmission at working temp. of the glass	Temp. of the glass turned towards the source of infra-red rays
Double-insulating glazing made of two sheets of clear glass $\frac{1}{16}$ in. thick, air space $\frac{1}{2}$ in.	72%	40°C.
Double-insulating glazing made of one sheet of clear glass $\frac{1}{16}$ in. thick and one sheet of athermic glass $\frac{1}{16}$ in thick facing the outside, air space $\frac{1}{2}$ in.	46·5%	60°C.
Double-insulating glazing made of one sheet of clear glass $\frac{1}{16}$ in. thick and one sheet of semi-reflecting glass $\frac{1}{16}$ in. thick facing the inside, air space $\frac{1}{2}$ in.	31%	40°C.
Double-insulating glazing made of one sheet of clear glass $\frac{1}{16}$ in. thick and one sheet of semi-reflecting glass $\frac{1}{16}$ in. thick facing the outside, air space $\frac{1}{2}$ in.	26%	45°C.

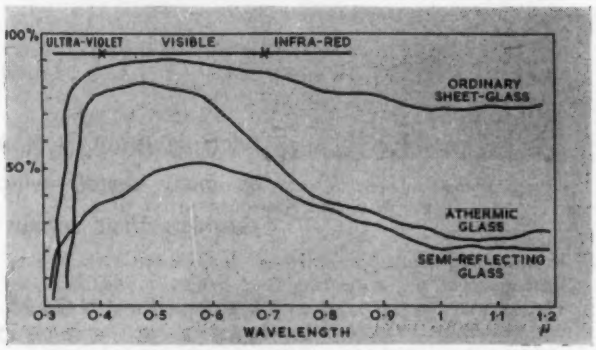


Fig. 1. Comparison of transmission of ordinary, athermic and semi-reflecting glass.

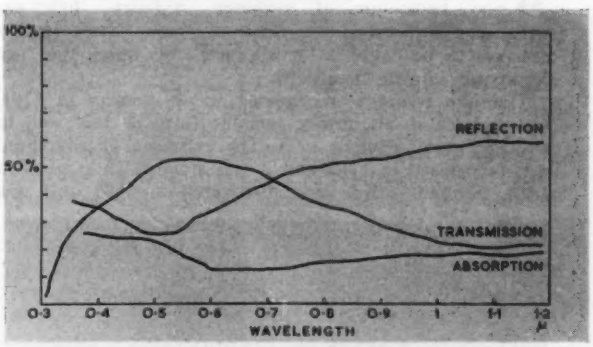
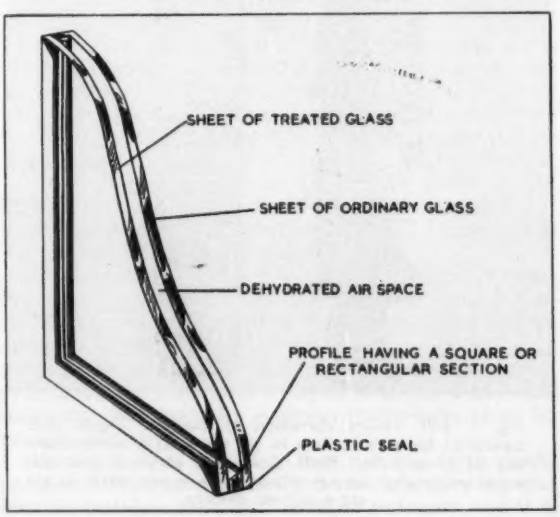


Fig. 2. Transmission, reflection and absorption of semi-reflecting glass.

Fig. 3. Section through a unit embodying semi-reflecting glass.


SHEET OF TREATED GLASS
SHEET OF ORDINARY GLASS
DEHYDRATED AIR SPACE
PROFILE HAVING A SQUARE OR RECTANGULAR SECTION
PLASTIC SEAL

CORROSION BEHAVIOUR OF SOME OF THE NEWER METALS

Exacting demands of post-war technology have forced the re-examination of many metals which had previously lain unexploited. This article considers their various reactions under corrosive conditions

by N. P. INGLIS, Ph.D., M.Eng., M.I.Mech.E., F.I.M., and J. B. COTTON, A.M.C.T., A.R.I.C.*

ALTHOUGH this article is concerned with the corrosion behaviour of tantalum, niobium, titanium, zirconium and beryllium, none of these metals strictly deserves to be called a "new" metal, by which they are commonly known these days.

Titanium was first recognised as an element in 1791, was isolated in an impure metallic form in 1825 and in a highly pure form in 1925. The existence of zirconium was recognised in 1789 and it was isolated as a metal in 1824. Niobium oxide was discovered in 1801 and was reduced to metal in 1929. The existence of beryllium was recognised in 1797 and it was first isolated in impure form in 1828 and made in reasonably pure form in 1898.

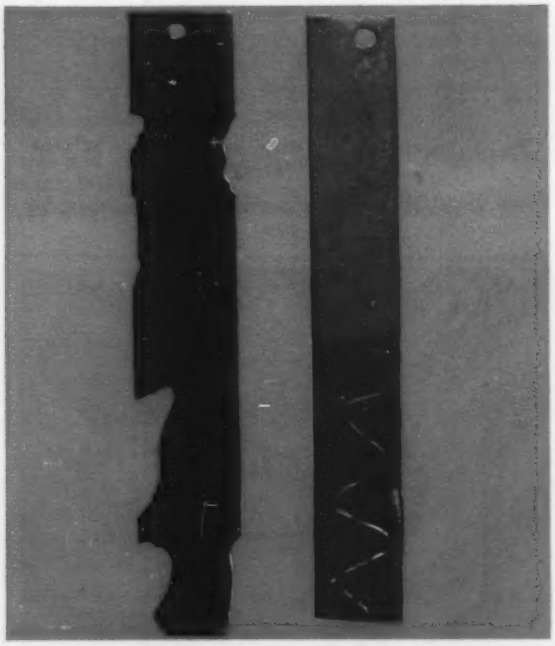


Fig. 1. *Left.* Severe corrosion of titanium anode after operation for a short time in sea water at a current density of 24 amp./ft.^{2} *Right.*- Composite platinum and titanium anode after long-term operation in sea water at the same current density.

It is, however, true to say that it is only in the post-war period that efforts have been made to produce most of these metals on a commercial scale and to carry out the considerable technological research on which their practical use must be based. This great stimulation of interest and effort has arisen from the development of industrial processes and operations which have been dependent for their success on new materials of construction.

Thus, the very rapid development of titanium, from what was almost a laboratory curiosity to an industrial metal made in quite appreciable tonnage, was due to the ever-increasing demands of the aircraft and aero-engine designers who can effectively and economically use titanium-based alloys which are as strong as high-tensile steel with little more than half the specific gravity, and which, in addition, have outstanding corrosion resistance. The rapid and still quickening interest in zirconium, beryllium and niobium is due to the value of these metals in certain types of nuclear reactors.

As in the past, metals or alloys developed for one specific purpose may have applications in other fields, and the corrosion resistance of some of these, particularly titanium, is of particular interest.

INTRINSIC REACTIVITY—A factor common to all these metals is that they themselves are so reactive that they will readily combine with oxygen to form oxides.

If the relative reactivities of these metals are compared by listing the free energy—or the heat made available during formation of their oxides—it will be seen that they are all much more reactive than the really noble metals such as gold and silver (see Table 1).

Even though these metals are not intrinsically noble, they are very resistant to corrosion under a very wide range of conditions. The reason for this lies partly in their very reactivity, for if they easily form stable oxides the oxide covering the surface of the metal can prevent further attack upon the metal itself.

* *Research department, I.C.I. Metals Division.* *This is a condensation of a paper presented at the annual meeting of the British Association for the Advancement of Science last autumn.*

TABLE 1. Standard free energies of formation of oxides (in K/cals. per mole of oxide)

Ta_2O_5	−471	TiO_2	−204	Au_2O_3	−39
Nb_2O_5	−423	BeO	−138	PdO	−20
$Zr\ O_2$	−244	NiO	−52	Ag_2O	−3

TABLE 2. Extent to which corrosion is suppressed by anodic polarisation of titanium

Corroding medium concentration by weight	Temperature (°C.)	Corrosion rate in in./yr. with applied anodic voltage of 1·5	Factor by which rate of corrosion is reduced
40% H_2SO_4	60	0·000028	33,000
40% H_2SO_4	101	0·0075	1,980
35% H_3PO_4	60	0·000156	400
35% HCl	60	0·005	670
50% formic acid (N_2 stirred)	101	0·0031	80
25% oxalic acid	100·5	0·0095	330

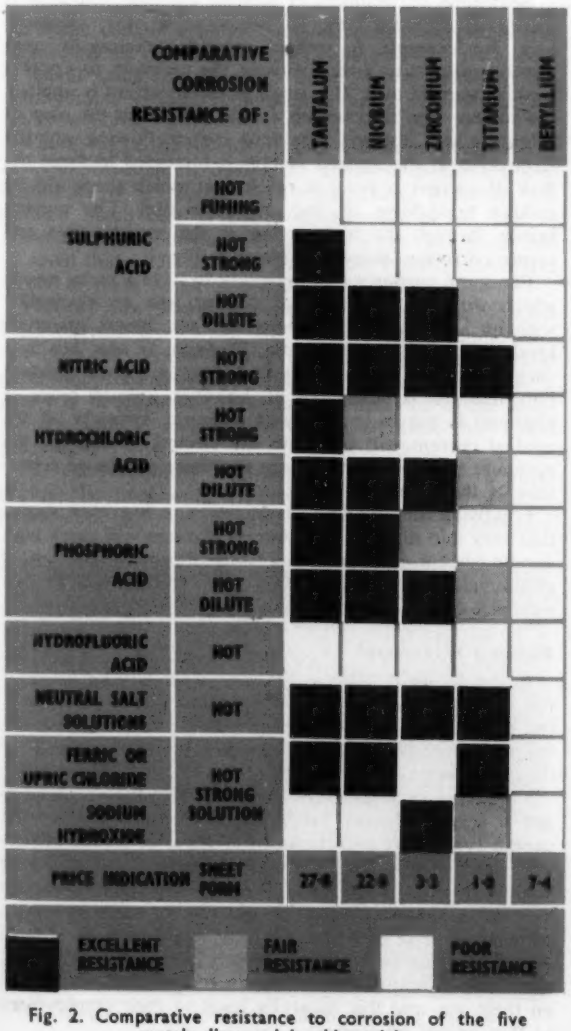


Fig. 2. Comparative resistance to corrosion of the five metals discussed in this article.

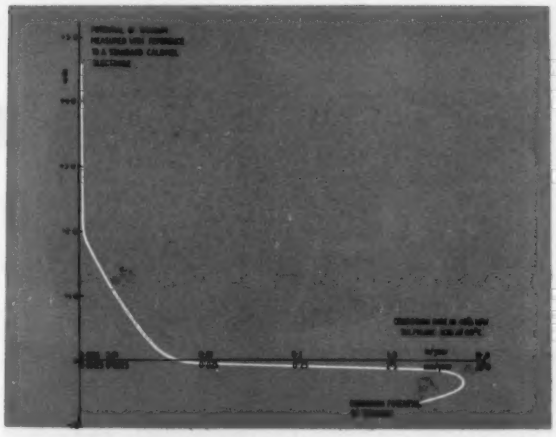


Fig. 3. Anodic polarisation curve for titanium immersed in 40 per cent sulphuric acid at 60 deg. C.

The mere presence of the oxide or surface film alone is not sufficient to confer good protection. To be really protective, these thin oxide films have to be very closely bonded to the metal surface; they have to hinder the passage of electrons and metallic ions between the underlying metal and the corrodent, and they have to be insoluble in the corroding medium.

It is mainly upon the basis of the behaviour of surface films that the corrosion resistance of these metals can be explained, and it is in this context that their fields of use may be considered.

CORROSION BEHAVIOUR—Corrosion behaviour is summarised in Fig. 2. In this chart, tantalum heads the list, followed in descending order of merit by niobium, zirconium and titanium. Beryllium is attacked in all really corrosive media. It is resistant to corrosion in fairly inert gases—hence its use as a canning material in gas-cooled atomic reactors. Being a light metal, it may conceivably find use for aircraft components—but it is not likely to be of much assistance to, say, the chemical engineer and it certainly cannot be classified, upon a corrosion-resistance basis, with the other elements mentioned.

The protective influence of the surface film is demonstrated by the fact that none of the metals is corroded under oxidising conditions, such as in the presence of nitric acid, where film repair can readily take place. With the exception of zirconium, all are attacked in strong caustic alkali and this, no doubt, can be attributed to the fact that the oxides themselves are weakly acidic and, as such, are likely to react in caustic alkali to form soluble tantalates, niobates and titanates. Hot-fuming sulphuric acid seems to be a universal solvent for most metals and these newer metals prove to be no exception. None is resistant to hydrofluoric acid and indeed, even in neutral ammonium fluoride, both zirconium and titanium are readily attacked.

It is interesting to contrast this behaviour with that of neutral chlorides. For example, it has been estimated that in sea water a titanium sheet as thin as a postage stamp would take 4,000 years to disappear.

It will be seen, however, that tantalum is the only member of this series to resist corrosion in hot strong hydrochloric acid—a fact that does not escape manufacturers and users of this acid.

From the price index at the bottom of Fig. 2, it is evident that there is a price to pay for superlative corrosion resistance. Sheet tantalum is almost twenty-eight times the price of titanium.

From these facts it is clear that economically it would be worth while attempting to lift the less expensive titanium into the tantalum class, for corrosion resistance, and it is

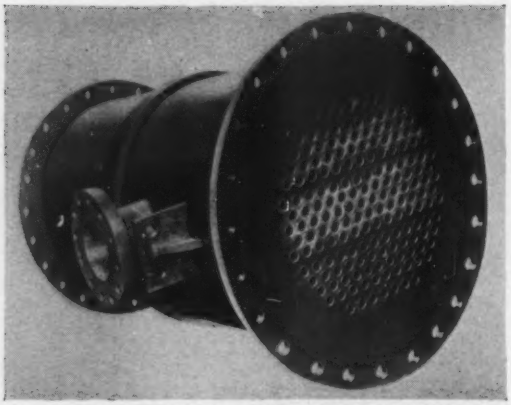


Photo: Fansteel Metallurgical Corp.

Fig. 4. Tantalum heat exchanger after ten years' service processing a high-purity chlorine product.

logical to reason that this would be possible if it could be made to form protective films in non-oxidising acids.

With some metals, growth of protective surface films is stimulated if the electrical potential of the metal is raised by connecting it to a positive source of d.c., a cathode connected to the negative terminal also being placed in the corrodent.

Aluminium and stainless steel may be induced to form surface films by this technique; and this is made use of in the well-known anodising process for aluminium. With metals or alloys such as aluminium and stainless steel, however, the conditions under which protection can be conferred by this means are limited to a few specific electrolytes or by a very restricted range of potentials over which the effect operates.

With these newer metals, and for titanium particularly, the growth of protective films can be stimulated in a wide range of non-oxidising acids and over a very wide range of potentials.

The method by which the potential is raised does not matter, provided a certain value of potential is exceeded and, in fact, in some corrosive solutions titanium can be protected by connecting it to a more noble element, such as platinum or carbon. The important point here is that under some circumstances protection can be afforded to titanium by a very thin porous film of more noble metal, and that there will be no galvanic corrosion at pores or discontinuities because at such regions the titanium will grow a protective film.

If then a titanium specimen is corroding in, say, hot strong sulphuric acid and if a small positive d.c. voltage is applied to it, there will at first be some increase in the rate of corrosion, but as the voltage is raised there comes a point at which a protective film is formed, and corrosion dramatically ceases. If the voltage is raised further, the film thickens up slightly and as it does so it changes colour, becoming first yellow and then blue and finally purple. The thickness of the film and the colour are specific to the voltage applied. Once the films have formed, there is only a very slight leakage of current into the electrolyte.

The mechanism of surface passivation can be followed graphically by recording the change of potential against the rate of corrosion. This is illustrated in Fig. 3, which shows that in 40 per cent sulphuric acid, held at 60 deg. C., corrosion has practically ceased by raising the potential of titanium to zero on the calomel scale, and that at a positive potential of 2·0 volts rate of corrosion is too low to be measured with any accuracy.

It has been demonstrated that this system of protection can be applied in a practical fashion to chemical plant constructed from titanium and operated under very corrosive conditions. In one such demonstration a welded titanium tank measuring about 1 ft. cube was connected by means of titanium tubes, 8 ft. long, to a centrifugal pump, also made of titanium. In this equipment, 40 per cent sulphuric acid was maintained at 60 deg. C. and circulated through the system for six weeks. Corrosion was completely suppressed by impressing a positive d.c. voltage of 2·3 between the tank and a cathode, protective films being formed even at the extremity of the system. The current consumption required to give this protection was 25 milliamps—equivalent only to 3 watts per thousand square feet of metal surface.

In this demonstration the protective current was supplied from a single storage battery, continuously trickle charged. Even after the protective current had been switched off, more than twenty-four hours elapsed before any appreciable corrosion ensued; complete protection was then re-established in six seconds by application of a pulse current. Under the corrosive conditions in which this test was made, unprotected titanium corroded at a rate of 1 in. per year and stainless steel at a much higher rate.

The extent to which application of anodic potentials can suppress corrosion of titanium in various non-oxidising acids is shown in Table 2.

Titanium under Impressed Current

Behaviour of titanium in neutral chloride solutions is somewhat different from its behaviour in, say, sulphuric acid; for example, in sodium chloride titanium is completely resistant to attack without the necessity to apply a positive current to it. If a small positive current is applied, the surface film thickens up a little and, as in the case of sulphuric acid, there is very little current flowing into the electrolyte. If the applied voltage is increased to force the flow of current, a point is reached at which there will be sudden breakdown of the protective film. The current breaks through the surface film at the weakest spot and severe corrosion ensues as shown in Fig. 1.

For some purposes it is necessary to have a metal anode which will conduct electrical current into an electrolyte without any corrosion. There are not many materials ideally suited for this purpose. Platinum is one, but it is very expensive. It is evident that, because of its resistant film, titanium is unsuitable. If, however, a small piece of platinum is put in contact with titanium, virtually all the applied current will pass into the electrolyte through the platinum at a fairly low voltage and there will be no corrosion of the titanium.

Following this trend of investigation, it has been shown that very thin films of platinum on titanium will carry high anodic current densities without breakdown, and the use of platinum-covered titanium electrodes is likely to find considerable employment in industry.

Future Potential

In the future it is likely that more use will be made of the newer metals, particularly titanium and zirconium, but unless some completely new cheap method of extracting these metals is found, none will become as cheap as iron, aluminium or copper.

For some purposes, the chemical industry is prepared to pay a very high price for equipment, provided its initial capital cost is not prohibitive in relation to the entire project and provided the equipment is likely to give a long trouble-free lift. (Fig. 4 shows a tantalum heat exchanger containing 174 tubes which has been in service processing a chlorine product of high purity for more than ten years.) As long as the cost of these newer metals remains high, there will, however, always be an incentive to economise on their use, and this naturally leads to their employment as thin linings on steel.

FERRITE MEMORY FRAME FOR ELECTRONIC COMPUTERS

ENGINEERING of metallic materials is sometimes an extremely delicate job due to the very small size of components to be handled. In the production of electronic memory units, for example, high-precision methods have to be applied in shaping, testing and assembling the often very tiny parts.

An assembly, called a ferrite memory, made up of thousands of tiny beads of magnetic material strung on a web of fine insulated copper wires, is being manufactured by the Radio Corporation of America for use in a high-speed electronic computer.

Equipment of this type is used for scientific computation, but other automatic computing devices with ferrite memories will be advantageous for the already overtaxed air traffic control systems. Such electronic computers will require higher speeds and greater capacities with the advent of jet airliners for passenger travel. Today, some of the giant computers often require more than a million memory beads or cores.

The cores in the memory frame will store thousands of items of information, having the ability to recall in a few millionths of a second this information, whenever requested. Each core is eighty thousandths of an inch in diameter or smaller than the head of a pin. The beads are so small that 6,250 of them will fit into a small matchbox; 83,000 of them weigh only one pound.

Ferrites are inorganic chemical compounds formed from metallic oxides and are widely used in components not only for computers but for television receivers and other high-frequency applications. Although ferrites are a post-war development, they have an ancestor in the lodestone, a natural magnet first recognised more than 3,000 years ago.

An extraordinarily high degree of control is required during the processing of ferrite cores because of their small size, light weight, and critical electrical tolerance limits. There are many separate steps in the production of the cores, one of the most significant of which is the high-temperature "banking" process used to produce the dense ceramic properties. In this step, the principal electrical characteristics of the cores are determined by heating them to a temperature between 1,100 and 1,350 deg. C.

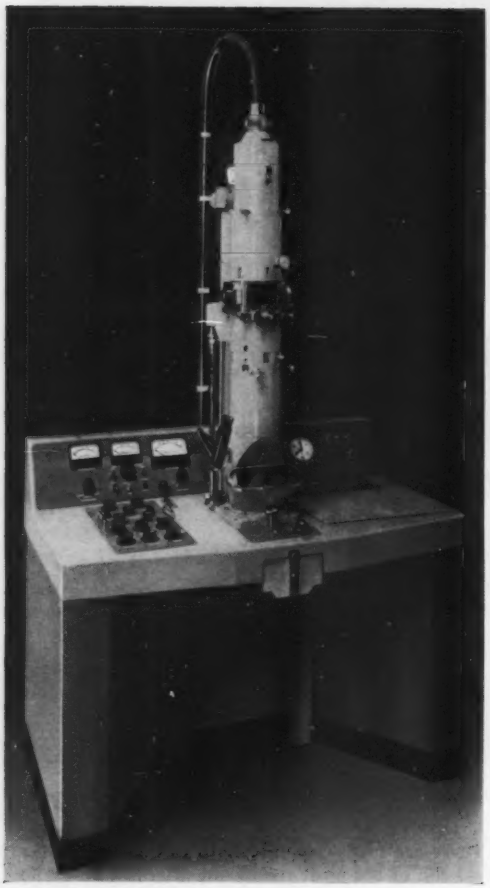
Testing four magnetic "beads" a second.

Inspection of memory core products presents a very real problem, as monthly production runs into millions. Each core must be individually tested for both electrical and mechanical characteristics, and this operation is performed on high-speed automatic equipment which can test as many as four cores per second. During the test, the core is subjected to the exact operating conditions that it will receive in actual computer use, and, in addition, these conditions are varied by the tester so that each core is tested at levels ten per cent below and above the specified operating conditions. It is claimed that this testing method provides cores of great reliability.

At the R.C.A. laboratories, the ferrite cores are assembled into a mesh-like square called a matrix. Skilled operators thread four thin insulated copper wires through the centre of each core. When completed, the matrix resembles a series of interwoven wires with the ferrite cores at each point where the wires cross. The matrix is then placed in a U-shaped aluminium frame, the design of which permits either vertical or horizontal mounting in the computer. Because the frame can easily be made in many different sizes or shapes, extra costs for special engineering or tooling on special core arrangements are reduced.

The A.E.C. computer memory will be among the first to use an assembled stack of R.C.A.'s new ferrite memory frames, where the sturdy aluminium construction offers mechanical strength and stability, and its compactness makes possible important reductions in the stacking height of frames within the computer.

Ferrite cores being stranded, viewed through a magnifying glass by the operator.



In the design of scientific equipment such as the electron microscope, operator convenience must be secondary only to purely technical considerations. This applies not only to observing and recording, but also to setting-up and maintenance.

INDUSTRIAL DESIGN IN ENGINEERING

True industrial design is more than a matter of sound engineering coupled with pleasing appearance. It must also reckon with safety, fatigue reduction and simpler maintenance—vital factors in the growing competition for overseas markets

by R. M. S. KAY, B.Sc. Tech., D.A.A., F.R.S.A.*

WHAT is industrial design or, as some prefer to call it, appearance or product design? How does it fit in with straightforward technical design?

The conference called by the Council of Industrial Design last autumn at the Engineering Centre in Birmingham was the first serious attempt to explain this to senior executives in the engineering industry and to indicate how this side of design could be dealt with in the interests of improving their products. That this is of increasing importance today, particularly in the export market, was emphasised by all speakers. In the past, industrial design has applied largely to consumer goods and articles handled through retail channels but less commonly to the heavier capital goods produced for industrial purposes. This had sometimes led to a misunderstanding on the part of engineering designers and a suspicion that it concerned only superficial appearance and, worse still, a fashionable styling of their products. Nothing could be further from the truth.

Industrial design is certainly concerned with appearances and finishes, in fact with the general presentation of the product, but it goes far deeper than that. Good industrial design, in its fullest implication, includes everything that will ensure the product being acceptable to the customer. In the engineering field the working specification for any plant is usually laid down; performance is stipulated and all technical design work can therefore be assumed to concentrate on this. Price and delivery times are naturally factors of paramount importance, and one must suppose that both sales and production departments will play their usual parts in determining these. But there are other things which must be considered if any piece of equipment is to appeal to a potential buyer when it is shown in a catalogue or at an exhibition and which, on being sold, will result in satisfaction leading to further sales. That is where industrial design can supplement the purely technical side of design and why it is receiving increased attention in what is rapidly becoming a buyers' market.

Even though a pleasing appearance is the ultimate aim, a good industrial designer does not attempt to achieve this by imposing it from the outside. He is no mere face-lifter, but lets appearance develop naturally as a result of what is contained within the product, and he allows this to control the general form and shape of the design.

Only when the function of a machine has been catered for can the exterior be considered, and even then the decision affecting the position of controls and instruments, the detailing of handles, lettering, etc., and such things as colour and applied finishes must all be subservient to the requirements of the operator, the erection and maintenance crews, etc. To commence with a preconceived idea of the final appearance, whether this is based on tradition or a fashionable idiom, is only to end up eventually with a dishonest and probably inefficient design.

This cuts out most forms of "design by eye" and replaces it with a more logical approach. In this, requirements are carefully analysed, alternative solutions examined and, finally, the most workable and yet likeable balance is struck by whoever is in effect responsible for the design.

Most engineering products require a team of designers to cover all the aspects involved, but final responsibility

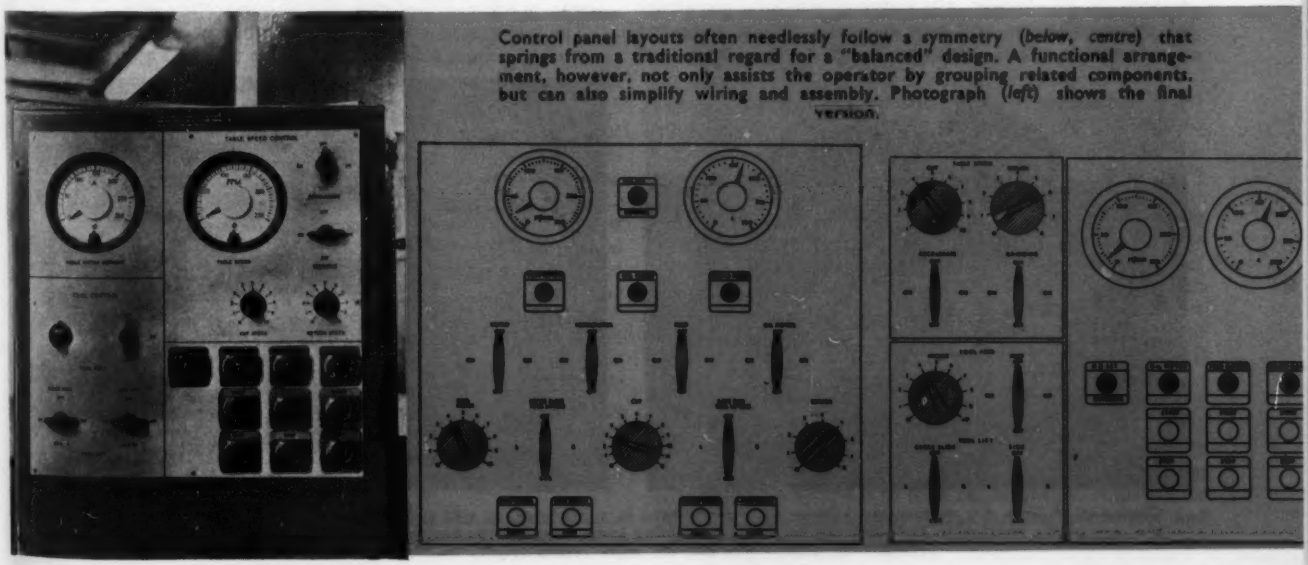
* *Industrial design engineer, Metropolitan-Vickers Electrical Co. Ltd.*

ORGANISATIONS CONCERNED WITH INDUSTRIAL DESIGN

Council of Industrial Design	28 Haymarket, London, S.W.1.	A government body, appointed to improve the standard of British design through manufacturers and the distributive trades. Though dealing mainly with consumer goods, has recently appointed an industrial officer for the engineering industry.
Design and Industries Association	13 Suffolk Street, Haymarket, London, S.W.1.	A self-supporting group of private members, manufacturers' stores, public bodies, etc., interested in the encouragement of good design. Regional branches in London, Manchester, Bristol.
Society of Industrial Artists	7 Woburn Square, London, W.1.	A professional body of commercial artists and product designers. Membership graded, according to experience, into fellows, members, licentiates (F.S.I.A., M.S.I.A., L.S.I.A.).
Royal Society of Arts	John Adam Street, Adelphi, London, W.C.2.	A society, as its full title implies, "for the encouragement of arts, manufacture and commerce". Grants a distinguished title to outstanding designers (maximum number 40, one in each branch) of Royal Designer to Industry (R.D.I.).
Institution of Engineering Designers	38 Portland Place, London, W.1.	A professional body of engineering designers and draughtsmen. Concerned primarily with technical and not with industrial design. Membership graded into members, associates, graduates and students (M.I.E.D., A.M.I.E.D., etc.). Activities in London, Yorkshire, North-east.
Royal College of Art	South Kensington, London, S.W.7.	One of the main training institutions for the younger product designer; has a section covering light engineering. Grants diploma (Des.R.C.A.).
Ergonomics Research Society	Secretary: Dr. O. G. Edholm, Medical Research Council Laboratories, Hampstead, London, N.W.3.	A group of medical, university and industrial research workers concerned with investigations into operator-machine relationships.
Federation of Engineering Design Consultants	St. Stephen's House, Westminster, London, S.W.1.	Mainly technical engineering consultants, but in a few cases covering industrial design.

usually rests with the chief engineer concerned. In this team, it is becoming increasingly accepted, the industrial designer has a part to play. He should take his place with other experts in this specialist age, whether he be a regular member of staff or an outside consultant. He should be brought in at the earliest practical stage, though this varies according to the nature of the product. He is usually an expert in matters artistic and ergonomic and can therefore supplement the work of his colleagues who have quite enough to look after in designing to a given performance. Being a member of the team, he is subject to the same give-and-take that calls for willing co-operation and teamwork. Though in the lighter field of the domestic product his opposite number may possibly design the entire article, in heavier engineering his work is restricted by the complexity of the problem. If he recognises these limitations, however, and fits in smoothly, he is a most acceptable addition to the team and one which the modern manufacturer cannot afford to exclude.

Ideally, industrial design should be practised by all engineering designers and draughtsmen. Names like Brunel and Telford are sometimes quoted to show that good



Control panel layouts often needlessly follow a symmetry (*below, centre*) that springs from a traditional regard for a "balanced" design. A functional arrangement, however, not only assists the operator by grouping related components, but can also simplify wiring and assembly. Photograph (*left*) shows the final version.

engineers need no assistance in this matter. But men of this calibre were exceptions and the changed conditions of production today call for specialists in all fields. It is important, however, that everyone responsible for design work should be aware of the main principles of industrial design and accept them as an underlying basis for their work. What, then, are these principles?

When, in 1915, the Design and Industries Association was founded in England, it adopted for its slogan "Fitness for Purpose". Though this was later considered a little stark as a definition of a well-designed product, it laid the foundation to a lot of clear, sensible thinking and today still forms the basic definition for good industrial design. Coupled with this one would include today a pleasant yet efficient appearance, the presentation depending on the particular machine or market. Appearance should arise naturally from both function and construction, anything that conflicts with this being false. Honesty in design is probably the most important principle to observe. It is perhaps fortunate that this coincides with economy in design, since "dressing up" usually costs more.

A study of the way in which a machine will be used, the operator-machine relationship which is dealt with today by ergonomic experts, is another very important factor in design. Unfortunately, it is only too evident that some machines are apparently designed for workers who are either 6 ft. 6 in. or 4 ft. tall; who have three right hands, one of which is about 7 in. wide; who must stand, or sit, for an indefinite period without wishing to change their positions; who can look at two instruments simultaneously though the dials are spaced too far apart; who, in fact, are expected to adapt themselves to a machine though the effort almost maims them. Both physiological and psychological knowledge is useful in planning such things as the efficient layout of components, the best practical shape for handles and the effort needed to move a lever in a certain direction. Much information has already been published on these subjects, particularly in the U.S.A.

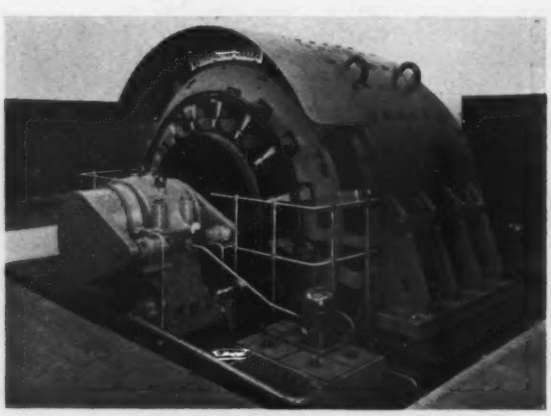
A rating or data plate is primarily for giving information. This example is one of a series which consistently provides title, data, full name and address, in that order. It is mounted at a convenient reading height and inside a door for protection, if possible. A separate plate with manufacturer's name can be displayed in a more prominent position.

Maintaining Balance

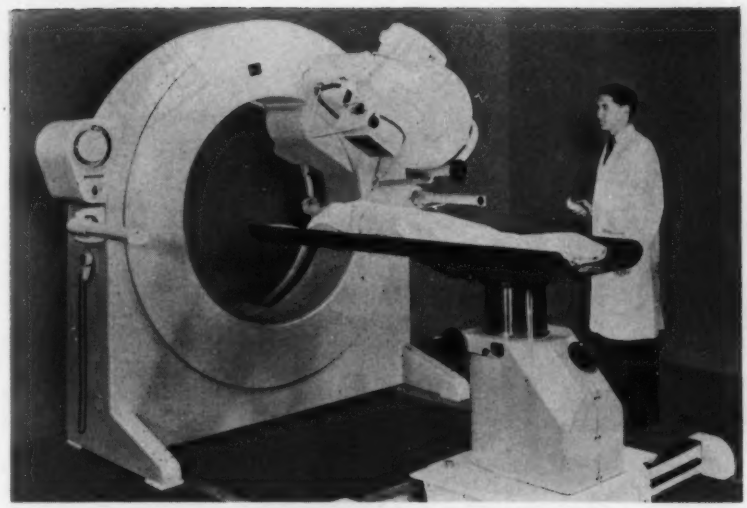
On the æsthetic side, the industrial designer has usually developed a sense for combining satisfactorily different shapes, whether flat outlines or solid forms; for arranging a layout of components on, say, a control panel so that attention is automatically drawn to the most important item or a complicated operation is simply explained; for blending æsthetic enjoyment of a form with functional reasons for its adoption. His training includes a knowledge of optical illusions and how to avoid certain undesired effects which might otherwise result, to the chagrin of himself. The behaviour of colours, particularly in combination, must be allowed for even on what is often a dull piece of heavy engineering. Discords due to colour clashes must be avoided, but sometimes a small patch of contrasting colour in the right place can work wonders in bringing a machine to life.

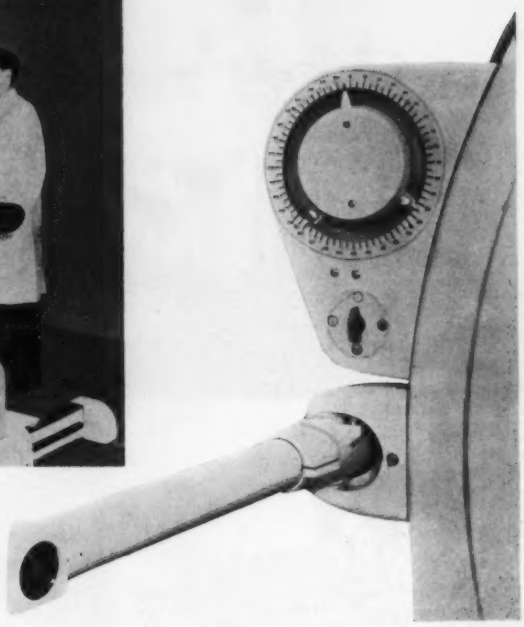
Despite his heightened perception, his main job in the æsthetic field may well be in dissuading technical designers from introducing some irrelevant bit of "artistic treatment" and in seeing that essential forms are allowed to express themselves naturally. Another very common form of dishonesty, arising perhaps from a misguided or untrained evaluation of visual appeal of a product, is to make shapes or combinations of shapes absolutely symmetrical about a centre-line which, in fact, does not exist. This form of balance appears to afford some people immense satisfaction, but when carried out at the expense of a functional arrangement can hardly be considered good design practice, either ethically or engineering-wise.

The question of ethics enters too when deciding how far a product should follow a fashionable trend, to appear up-



Closing-in of large d.c. motors can achieve an improvement in appearance, as well as in safety and ventilation control, as in the case of the endshields. Enclosing the feet and eliminating some flanges looks better and avoids dirt-traps, as a comparison between the older (*left*) and the more recent (*right*) machines shows.





The engineering problems in providing a smoothly-balanced mounting for the Cobalt 60 medical unit dominated the design of the Orbitron. *Right:* Note the attention to detail.

to-date, how far it should favour traditional lines, to appeal to the die-hards and to use standard parts, how far it should disregard either and be strictly functional. So much depends on a careful analysis of market requirements which vary for different types of products and in different communities (industrial or national), and a skilful choice must be made if the product is to have maximum appeal. From this point of view a designer who can review the position from outside the company, uninfluenced by sentimental attachments to previous favourite lines, can often assess the customers' reactions better than can an inside man.

Using Outside Consultants

This brings up the point of using industrial design consultants in addition to permanent staff. It also entails a brief comparison between the use of inside and of outside design specialists. Since the former can only obtain suitable (evening or part-time) supplementary training in the larger centres, such information can best be sought from books, periodicals, exhibitions, visiting lecturers or other activities arranged by those responsible for staff training.

Generalisations can be very misleading in a subject like this, so much depending on the size of the firm, its existing organisation, etc. As a guide, however, the following remarks may be taken to apply to average cases:

(a) In larger firms the use of internal specialists is usually justified. These would co-operate with the technical design teams, as required. They must be given reasonable opportunities (travel, etc.) of keeping in touch with the world outside the firm's boundaries.

(b) In very large organisations an industrial design centre* may also be justified. This would plan the work of the specialists; carry out training schemes for the staff; obtain and circulate up-to-date design data to all design offices; hold internal exhibitions and take other steps to encourage good design not only in products but in the background which is likely to affect the daily outlook of designers.

(c) In smaller firms, where even one specialist could not be employed full-time, the visiting consultant is a useful expedient.

This may be on a basis of regular visits which act first as stimulants then gradually develop an improved design policy by slow absorption. Alternatively, a consultant may only be brought in to provide special designs when required. Every chance should be given for such short-term operators to assimilate all the necessary background affecting the most economical production of goods under the particular conditions of firm's plant and labour skill available.

(d) The use of visiting consultants, under either of the above systems, may be equally advantageous for a larger firm, for several reasons. It might be able to obtain, for short spells, the services of a designer of national repute. The benefit of a wide and continually enriched experience could be gained by contact with different industries. There is the advantage of receiving unbiased views from someone whose nose is not too close to the firm's grindstone. Speeding up of design and development work is also often necessary to keep up with the visit programme.

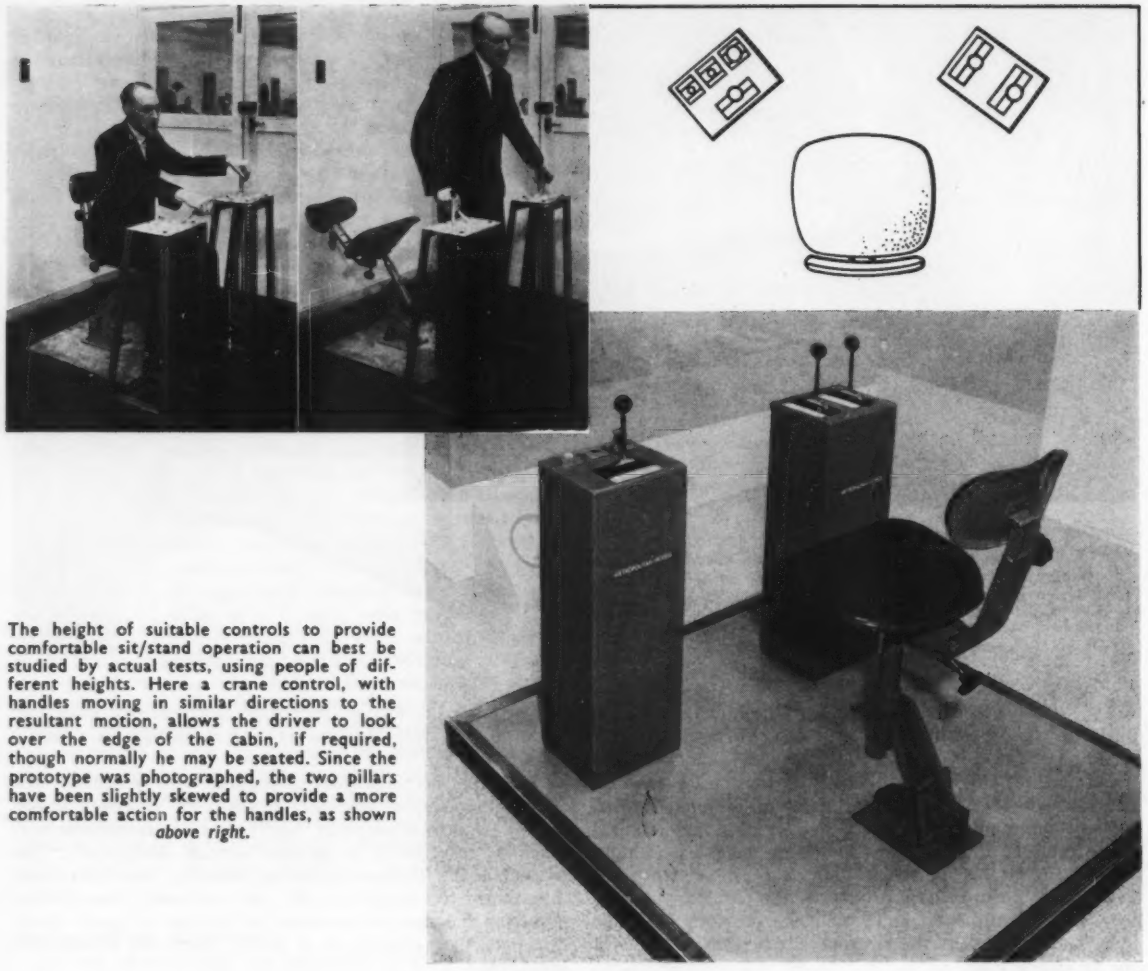
A combination of the two methods mentioned at (c) is sometimes used and further variations are available to suit special circumstances. In the author's company, although a design centre operates full-time, regular visits are also made by an outside specialist.

Terms of payment for non-staff designers vary, being made in some cases initially for the design itself with perhaps further payments on a royalty basis on sales. In other cases, design work may be put out for the consultant to handle in his office on a cost-plus agreement. Again, a retainer may be paid to cover general advice over a fixed period or for a series of visits.

Obtaining Advice

In this country, the Council of Industrial Design renders a valuable service in assisting manufacturers to engage consultants most suited to their requirements. Applications to the Council are treated in the strictest confidence and firms with no experience of employing industrial design

* "Plan for a Design Centre in an Engineering Firm", *Design*, August 1949.



The height of suitable controls to provide comfortable sit/stand operation can best be studied by actual tests, using people of different heights. Here a crane control, with handles moving in similar directions to the resultant motion, allows the driver to look over the edge of the cabin, if required, though normally he may be seated. Since the prototype was photographed, the two pillars have been slightly skewed to provide a more comfortable action for the handles, as shown *above right.*

specialists, either staff or consultants, may obtain most useful advice in this matter, also in such things as staff training.

Several other valuable organisations in this field are mentioned in the table on page 83, which also indicates the scope and activities of each group and its interest in industrial design.

It is perhaps unfair to other training establishments to single out the R.C.A. for mention, but this has been done in acknowledgment of the college's rather special position and so that its award of Des.R.C.A. may be noted. A recent White Paper (Circular 340, July 14, 1958) from the Ministry of Education hinted that closer co-operation from colleges of art and of technology, and of industry itself, will be necessary if practical courses in product design are to be available to engineering students. The fact that industrial design is now recognised as an endorsement subject to O.N.C. by the Institution of Mechanical Engineers shows that at last serious attention is being given to this subject.

In a shrinking world of increasingly competitive marketing, neither this country's fine traditions from the past, nor such present achievements as our speed records in the three elements, will influence potential customers. For most engineering products value for money must include an attractive appearance and a thorough appreciation of the operators' requirements. This applies particularly to such things as machine tools and equipment for clean, modern factories and research establishments.

Appearance rates high, too, in engineering products that will be seen by the general public whose tastes are becoming more sophisticated. This is recognised by such bodies as the Post Office and British Railways, where industrial designers are called in to improve telephone kiosks, modern rolling stock and locomotives, though in the latter case they can naturally only cover certain aspects of the design work.

Attempts to "tack on" a good appearance to a badly-designed product usually results in some of the worst cases of bogus streamlining or modernistic styling. Sticking to bare engineering considerations would in most cases produce a very much better product, but, unfortunately, it is doubtful whether this would satisfy the demands of today's customers, whether at home or abroad. There is probably a direct link between the rising standard of living throughout most of the world and the tastes of the average customer.

As more time becomes available for the pursuit of cultural activities, and as a result also of the educational effects of television and easier travel, the standards of taste are likely to rise still further. The corollary to this is that more and more attention should be given to user-product relationships. Since technical design is getting more complicated, with each aspect being dealt with by specialists, it would seem that expertise will also be needed in the practice of industrial design.

NEW IDEAS IN DESIGN

Outstanding products in current manufacture

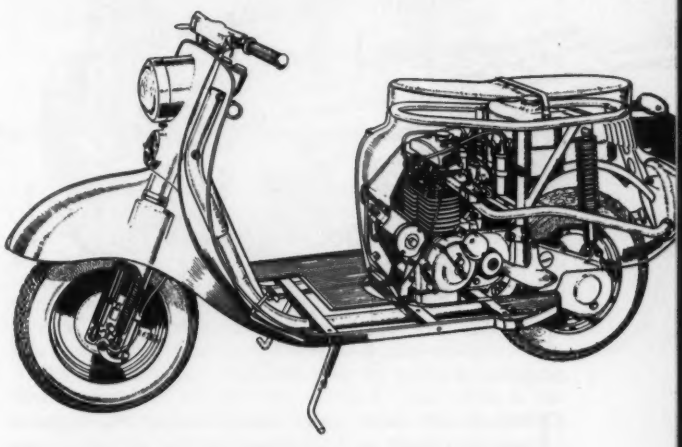
Unusual Features of New British Scooter

THE B.S.A. Sunbeam scooter, although bearing a superficial resemblance in its outward configuration to scooters of continental origin, embodies several interesting new features.

The model illustrated has an o.h.v. vertical twin engine of 249 c.c. capacity. The cylinders, crankcase and gearbox shell are cast as a single unit in aluminium alloy, the iron alloy liners being cast in position. A turbine fan, which forms a part of the external flywheel, is used for cooling. An a.c. generator is provided, the stator of which is bolted to the crankcase end cover. A self-starter can be supplied as an optional extra. The gear change is operated by a pedal which is moved backwards to change up and forwards to change down, the pedal returning to a central position after each change. Another pedal is provided for putting the gear in neutral.

The final drive is carried by a Duplex roller chain running in a stressed cast-aluminium oil bath chaincase which acts also as the swinging arm unit of the rear suspension. The final drive sprocket is splined to the rear axle through a vane cush drive with synthetic rubber elements.

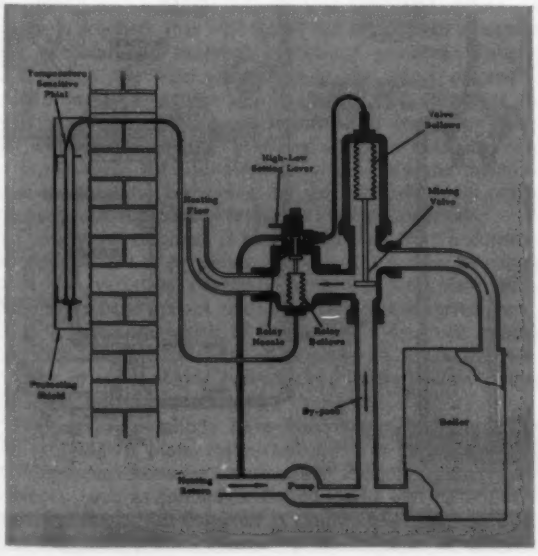
The front suspension is novel in that the stub axle is carried by two telescopic legs, one behind the other, on the left side of the machine. The lower ends of the legs



are located in a cast aluminium housing which carries the stub axle. The front leg contains a hydraulic damping unit, the rear leg the main suspension spring. Front and rear wheels are interchangeable.

Valve for Automatic Control of Central-heating Systems

THE Satchwell BMT mixing valve has been developed for use with small pipe-heating systems, where an electric pump is used to circulate the water through the radiators, without interfering with the domestic hot water supply from the same boiler.

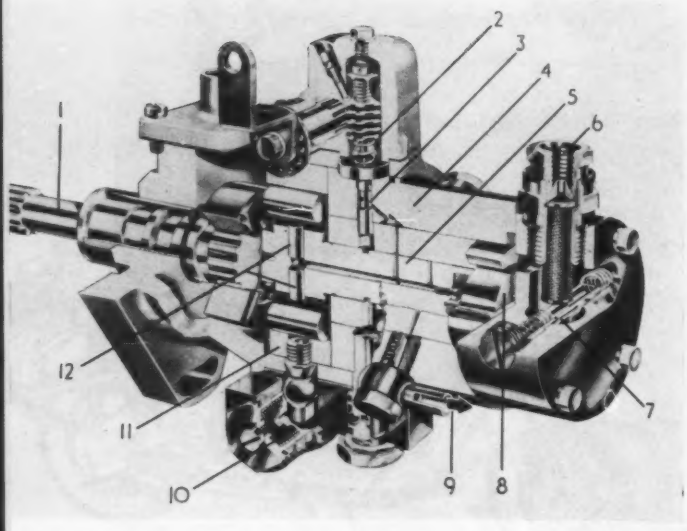


A temperature-sensitive phial on the outside of the house is connected to the valve by capillary tubing and controls the mixing action of the valve. Sudden changes in outside temperature are thus catered for in advance by the valve, which makes the necessary alteration to the hot-water flow to the radiators. The motive power of the valve is derived from the pressure differential across the circulating pump, for which a minimum circulator head of 4 ft. is necessary.

The boiler control is pre-set to a value between 66 deg. C. and 82 deg. C. according to the maximum temperature which it is thought might be required for the heating circuits and, since the domestic hot water cylinder (indirect type) is connected directly to the boiler, the hot water supply is unaffected by the heating control. Similarly, a large demand for hot water will not noticeably affect the heating circuits. It is essential that the boiler be fitted with a thermostatic control to maintain reasonably constant boiler temperature.

Contraction of the liquid in the phial causes the relay bellows to contract and open the relay nozzle port and so admit water under pump pressure to the mixing valve operating bellows. A high-low setting control is provided so that a reduced house temperature can be maintained at night or during unoccupied periods, while a boost adjustment is also provided to allow full boiler temperature in the heating system after a shut-down.

Distributor-type Fuel Pump Uses One Pumping Element

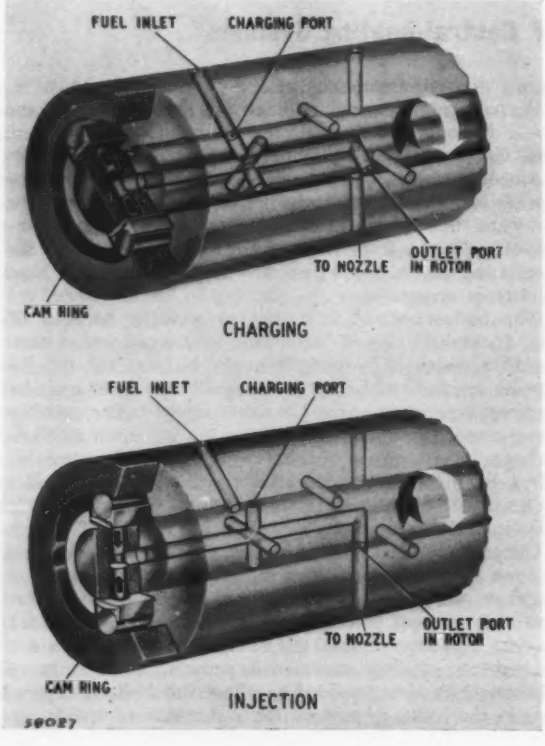


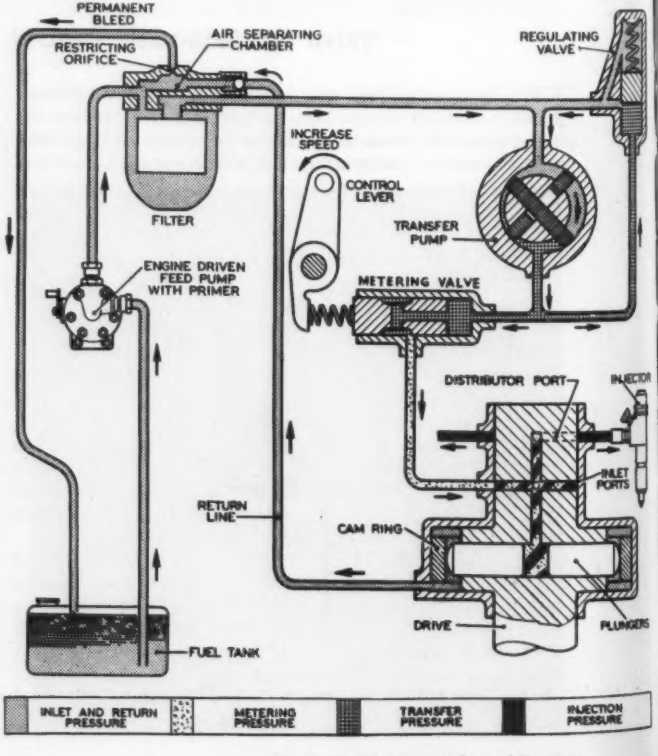
THE C.A.V. DPA pump, which employs two opposed plungers fitted in a common cylinder at right angles to the axis of rotation of a central rotating pumping and distributing rotor, is suitable for both small high-speed diesel engines and also for those of larger size. As the output from the pumping element is constant, no separate adjustment for equal delivery of fuel to each cylinder is necessary, as is the case with the in-line type of pump. The pump is relatively simple and compact in design, contains no ball or roller bearings, no gears and no highly stressed springs. The parts move in and are lubricated by filtered fuel oil. The pump can be supplied with mechanical or hydraulic governor and can be mounted in either a vertical or horizontal position.

A transverse section of a pump fitted with hydraulic governor is shown above. The three main rotating units, which are arranged on a common axis and rotate together, are the main drive shaft (1), the pumping and distributing rotor (5), and a fuel transfer pump (8). The distributor rotor, which rotates in a stationary hydraulic head, is driven by the drive shaft (1) by splines, the shaft being carried in a sleeve in the base of the pump housing and having a further set of splines for coupling to the engine drive. The pumping section of the rotor carries the opposed pumping plungers (12) which are operated by means of a stationary internal cam ring (11) through rollers and shoes. The cam ring is provided with as many lobes as there are cylinders to be served.

The distributing section of the rotor contains a central axial passage which connects the pumping space between the plungers with ports which are drilled radially in the rotor and provide for fuel inlet and delivery. A single hole in the stationary hydraulic head communicates with a number of ports in the rotating head, according to the number of engine cylinders, while a single outlet hole in the rotating head aligns successively with the same number of holes in the hydraulic head to supply the fuel injector nozzles.

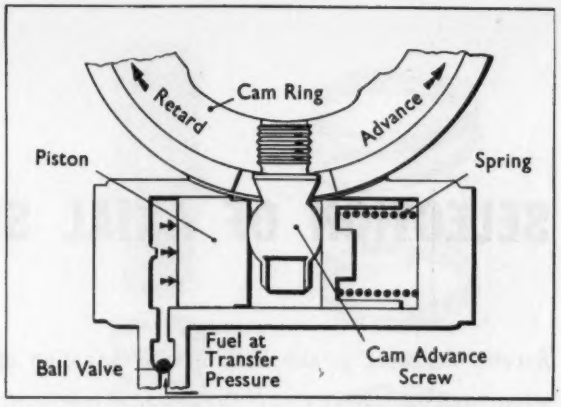
Fuel entering the pump flows first through the vane



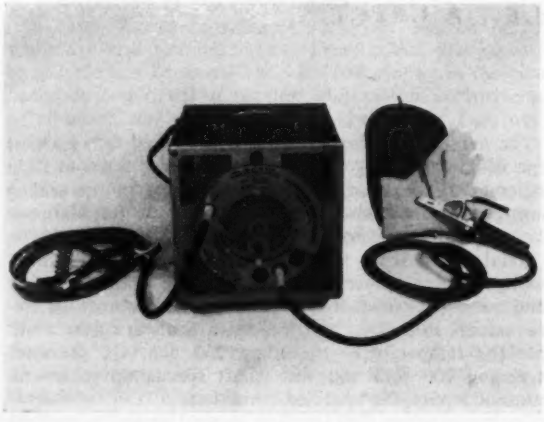


transfer pump (8) which raises its pressure to an intermediate level. It then flows down a passage in the fixed hydraulic head to the metering port (3) and thence to the pumping plungers, which it forces apart. Further rotation of the rotor causes the plungers to be forced inwards by the cam ring lobes and the fuel is forced along the central hole and thence outwards to one of the distributor ports.

The amount of fuel injected is controlled by the metering valve and the effective pumping stroke of the plungers, which can be altered by two cams which control the outward travel of the cam roller shoes. On some models an additional feature is a control mechanism which provides automatic advance of the point at which fuel injection takes place, by rotating the cam ring within the pump body. A ball-ended lever projecting from the cam ring is moved by means of a small piston, operated by transfer pump pressure which increases with speed.



Silicone-glass Insulation for Portable Welding Transformer



THE Fararc 200, a fan-cooled toroidal arc-welding transformer which can be connected to 200/250 or 400/440-volt mains, has a power factor of between 0·8 and 0·9 and no correction condenser is necessary. Combined with high power factor, the set has an open circuit voltage of 50 volts, for which a wide selection of electrodes is now available. The makers point out that the use of this low voltage offers increased operator safety.

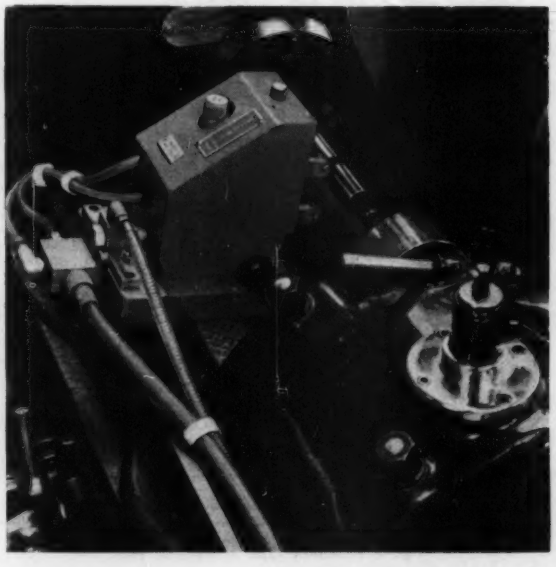
The set uses glass-insulated wire throughout, wrapped, where necessary, in glass woven cloth. The whole is impregnated with silicone varnish and baked. No combustible materials being used in its construction, the set can operate without damage up to 180 deg. C. For protection against the unlikely event of overheating, a thermostatic switch is incorporated which cuts off the welding current but leaves the cooling fan running. A junction box is available to enable two or more sets to be coupled together to give 400, 600 or 800 amps.

Automatic Size Guiding of Splined Shafts

THE Sigmatrol, a compact electro-pneumatic unit, makes possible the automatic control of some machine tools through a gauging head which measures the size of the workpiece and stops the machine when the correct size has been reached. It is well suited for the control of centreless, internal and external cylindrical grinders. Gauging directly on the workpiece reduces the effect of uncontrolled variable such as wheel glazing and spring of the machine or work, all of which can affect consistent sizing, particularly when plunge grinding against a fixed stop with a timed dwell. An additional provision on some machines is the automatic retraction of the wheelhead for wheel dressing and subsequent in-feed at pre-set intervals.

The general principle is that air flowing from a constant pressure source is permitted to escape at a rate dependent upon the variation of the size of the workpiece being ground, from a pre-set size. This flow is converted into a variable pressure which is applied to a sensitive capsule carrying a set of contacts which make or break the relay circuits in the machine control mechanisms, when critical pressures have been reached.

Previous applications have been concerned only with the grinding of plain cylindrical surfaces. With the latest development, however, automatic sizing of interrupted surfaces, such as splined or flatted shafts can be achieved, provided that a full diameter is available for measurement. This has been made possible by the addition of a special circuit into the system which differentiates between the large and small variations in pressure which alternately occur as the breaks and lands pass the jets.



SELECTION OF AXIAL SHAFT SEALS

Recent increases in the U.K. in the handling of liquids and gases have stimulated many advances in the design of mechanical shaft seals. This article discusses their characteristics and selection for general engineering uses

by P. L. McILWRAITH, A.M.I.Prod.E., A.I.Pat.E.*

SEALING of rotating shafts against corrosive and abrasive process fluids, with the trend towards higher process temperatures and pressures, has called for the use of new materials by designers of shaft seals. Their efforts have produced seals now being used successfully in conditions considered unworkable two or three years ago.

Selection of an appropriate seal for a given application is important, and should be given equal priority with the specification of bearings and similar items. It is not always appreciated how vital it is that shaft seals should be specified when laying down the overall design of equipment. Early attention will ensure that the most suitable type of seal can be fitted and can save valuable time later on. An appreciation of the functions of the various types of shaft seal will ensure the selection of the most appropriate item.

There is often confusion about the precise function of an axial shaft seal as well as its construction and, consequently, its limitations of use; a definition would therefore be of value here before discussing specific applications.

* *Industrial engineer, Short Bros. & Harland Ltd.*

The axially-mounted mechanical shaft seal is a packless type of gland having two flat sealing faces fitted at right angles to the shaft axis. Flexible mounting of the sealing rings permits axial movement to compensate for shaft end play, deflection, eccentricity and face wear.

Axial shaft seals should be chosen for applications having rotating rather than reciprocating shafts. Limiting conditions are constantly under revision, because of improvements in designs and materials. Seals are now available for temperatures exceeding 260 deg. C., pressures exceeding 700 p.s.i and with shaft speeds up to several thousand r.p.m., for specified conditions.

Conventional packed stuffing boxes, having a packing medium forced into contact with the shaft, have inherent disadvantages. Inability to control leakage, wear or overall effectiveness are factors which have necessitated the development of today's simple but efficient axial sealing units.

Large-scale manufacture of domestic refrigerators after the First World War created the need for quantity production of mechanical seals. Simple types of shoulder seal

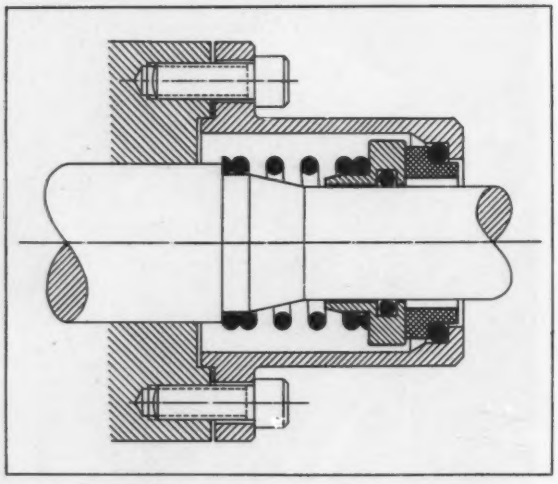


Fig. 1. Flexibox type R internal seal.

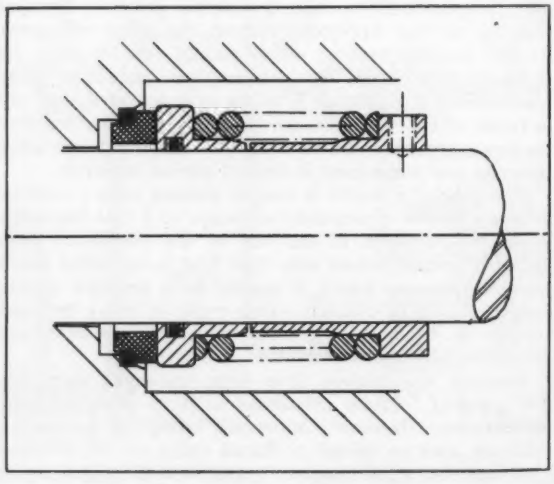


Fig. 2. Flexibox type F external seal.

had been used before 1900, but it was not until after 1939 that the forerunners of the present types of seal appeared in the U.S.A. Full development in the U.K. did not occur until after 1945, although at least one seal of this type was produced in quantity by a company during the war.

Types of Axial Seal

Basic components of the axial seal, as shown in Figs. 1 and 5, comprise a stationary rubbing ring, a rotating sealing ring, a static seal and a pressure spring.

Types of seals, assembled from these components, include those with:

(1) Single or double assemblies of seals.
(2) Internal or external sealing faces.
(3) Balanced or unbalanced sealing faces.
(4) Stationary or rotating sealing ring.

Extra features, which are available to ensure satisfactory performance of the seal in adverse conditions, include circulation or flushing facilities. These provide cooling or heating of the gland, pressurisation to avoid loss of costly or abrasive media, pressure lubrication of the sealing faces, or recirculation of the process fluid.

SEALING RINGS—Axial seal design is centred on the stationary and rotating sealing rings, which are expected to provide low frictional loss, effective sealing in the given operating conditions of varying temperature, corrosiveness or abrasion, and a predetermined low rate of face wear, without sticking.

Requirements for the rings include their location at right angles to the shaft axis, especially for high-speed applications. The materials of the rings must ensure rigidity in service in order to eliminate distortion and consequent leakage.

The pressure : velocity ratio of sealing faces is important in selecting seal face materials. The sum of the pressures acting on the faces (derived from the spring and from the hydraulic pressure of the fluid) and the velocity of the face materials at the diameter to be used must be considered in conjunction with the lubrication of the sealing faces, their surface quality, and the operating temperature.

The stationary face is normally non-metallic, frequently of a compounded carbon material. A carbon-graphite compound provides self-lubricating properties and a low coefficient of friction, especially desirable for applications where the sealing faces must be run in a dry state.

Hardness and strength of the ring are increased if the carbon-graphite base is treated with metallic or plastics

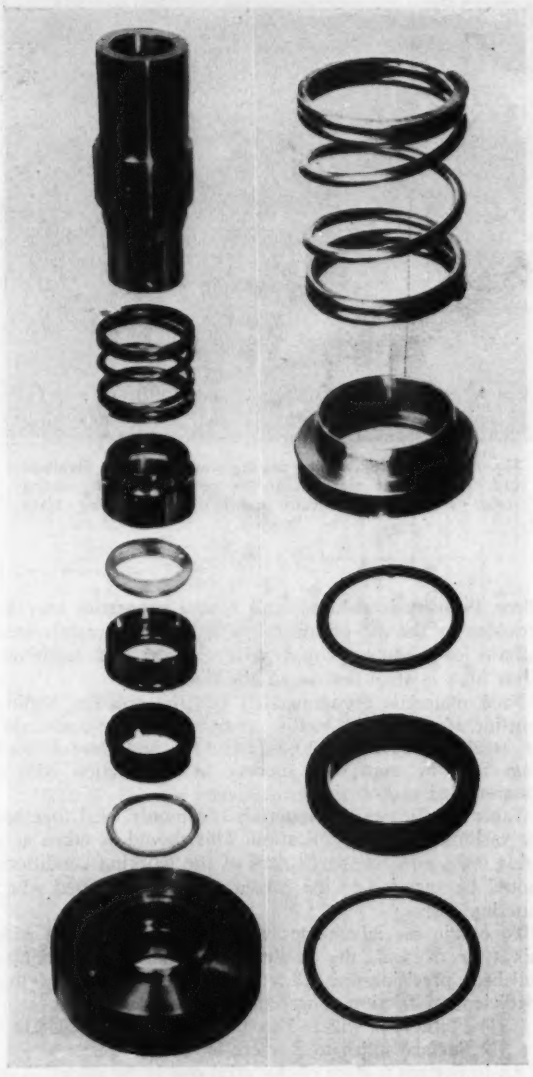


Fig. 4. Left: Components of the Flexibox type RRATCQ axial seal.

Fig. 5. Right: Components of the Flexibox type R axial seal.

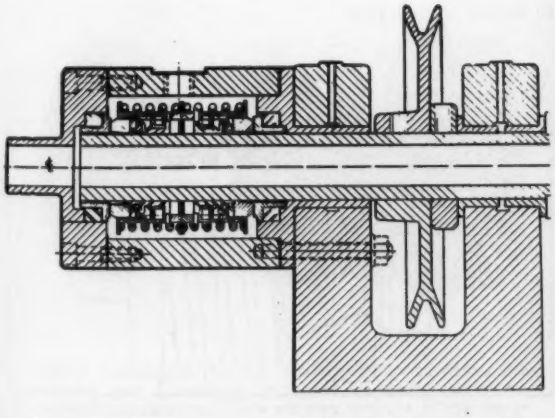


Fig. 3. Application of a Crane double seal for vacuum or compressed air service. Space surrounding the seal is filled with light lubricating oil.

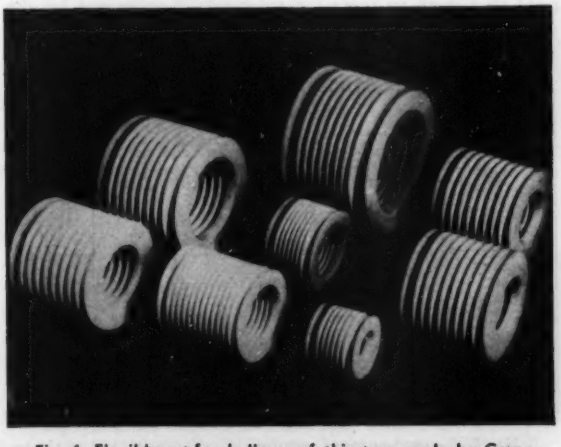


Fig. 6. Flexible p.t.f.e. bellows of this type made by Crane Packing Ltd. are suitable as connectors for operation in contact with corrosive chemicals, solvents and lubricants.

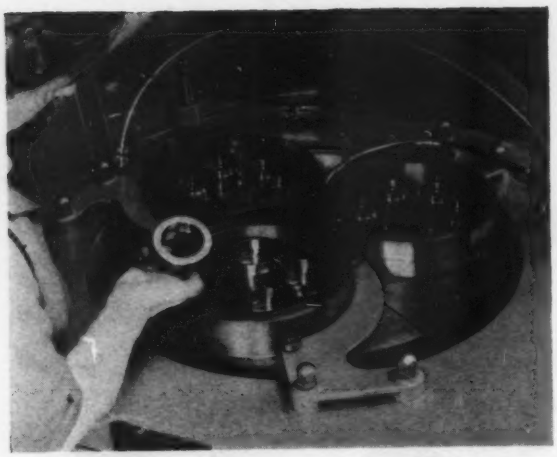


Fig. 7. Machine for lapping sealing rings, made by Flexibox Ltd. Top left of picture can be seen the spring-loaded roller which automatically controls the lapping plate flatness.

fillers. Porosity is reduced, and special properties may be provided by the use of suitable additives. The metals used include lead, copper, copper alloys, silver and cadmium. Glass fibre is also used as an additive.

Face materials recommended for the rotating sealing ring include cast-iron, stellite, tungsten carbide and stainless steel. For corrosive fluids, ceramics- and plastics-faced rings may be used with success, in conjunction with a compounded carbon ring.

Table 1 indicates the materials commonly used together for various types of application. This should be taken as a guide only, and full particulars of the working conditions should be supplied to the manufacturers concerned when ordering seals.

To obtain the advantages which may be achieved with this type of seal, the sealing rings must have highly-polished, precision-finished rubbing surfaces with a low coefficient of friction. The requirements are:

(1) Flatness to within 3 to 5 light bands (0·000058 in.).

(2) Surface finish to 5 micro-in. r.m.s. value.

An important feature of the axial seal is the retention of a thin film of lubricant between the rubbing faces, except in those few cases where dry running faces are necessary. The surface finish requirements are designed to minimise friction while permitting the retention of lubricant. The need to adhere to these critical limits is increased by the small face area of the mechanical seal, compared with the area of contact in the packed type of gland. Lapping machines are available for this work; one type developed by a British manufacturer of mechanical seals is capable of finishing the surfaces to one light band of flatness and 2 micro-in. r.m.s. value surface finish.

In this machine (see Fig. 7), which is made in two sizes, the components to be lapped are held within three wear rings held in three workholders on the top of the lapping plate. The work, workholders and wear rings are caused to rotate on the lapping plate by frictional drag. Both the plate and wear rings, which are fed at a controlled rate with lapping compound, are made from close-grained cast iron.

STATIC SEALS—Usually O-rings of synthetic rubber, static seals provide the sealing effect between the shaft and the rotating seal face and between the casing and the stationary seal face. These seals are static, relative to their housing, and should be located in accordance with the makers' instructions. The surface of the shaft, or other part in contact with the static seals, must ensure good sealing without binding. Diaphragms are sometimes used to replace the static seal which is associated with the rubbing ring.

PRESSURE SPRINGS—In a balanced seal, the spring provides the total force tending to keep the sealing faces in contact, and also provides the drive for the rotating seal face. Axial float of the rotating ring is a function of the spring which, in a seal mounted within the process fluid, must be proof against any adverse properties that the fluid may possess.

In a specially developed seal for use on drive shafts passing through bulkheads or explosion walls on ships, a number of compression springs on the outside of the seal enable a considerable degree of malalignment to be tolerated.

High temperatures and corrosive fluids supply the most difficult conditions for the pressure springs.

One of the latest developments is the use of springs coated with p.t.f.e. (polytetrafluoroethylene) to combat chemical action. This material can be used in contact with all concentrations of acids and salts, strong oxidising or reducing agents, and is resistant to all organic compounds.

The resilience of the spring provides the compensation for machining tolerances, wear and deflection, which is a major advantage of this type of seal.

Metal or plastics bellows of the type shown in Fig. 6 are sometimes used in place of, or in addition to, the pressure spring. This component would normally be used in the low- and medium-pressure range. The carbon rings are commonly nickel-plated and soldered to the metal bellows to ensure a good joint.

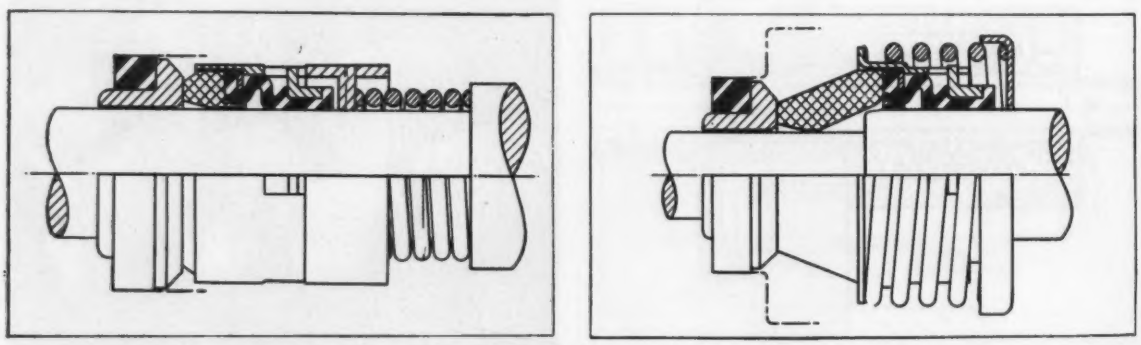


Fig. 8. General-purpose rotating single mechanical shaft seals by Crane Packing Ltd., suitable for light to medium duties. Left: Unbalanced type 1A, for fitting into existing stuffing boxes where o.d. is limited and length is a secondary consideration. Right: Balanced type 2, for existing stuffing boxes where length is restricted and o.d. is of secondary importance.

Control of the initial compression of the spring is important to the correct functioning of the seal. Insufficient compression will cause the sealing faces to open under working conditions, while excessive compression will increase the power consumption of the seal, and will reduce the life of the sealing faces. Seals mounted externally must receive careful attention to ensure adequate compression, since in most cases there is no hydraulic pressure to assist the closing action.

Selection of Seals

The first task in selecting an axial seal is to determine the operating conditions which effect its function and the materials of which it is made.

The following are the main factors that any manufacturer of seals will need to know in specifying from the types available. Special conditions, unique to the particular application, should also be listed.

Use of Table 2 will assist the equipment designer to locate the most suitable type.

(1) Type of equipment.
(2) Shaft details:
speed; diameter; material; surface finish; permitted end-play; permitted eccentricity; permitted run-out; direction(s) of rotation.
(3) Material of sealing chamber.
(4) Dimensional limitations of sealing chamber and adjacent items.
(5) Properties of fluid or gas to be sealed:
corrosive properties; abrasive content; lubricating properties; permitted leakage; working pressure; maximum pressure; viscosity and volatility.
(6) Direction(s) of pressure.
(7) Special conditions:
steady or intermittent service; explosive properties of gas or fluid: special assembly conditions; required working life; any other relevant factor.

SINGLE OR DOUBLE-SEALS—Single seal assemblies, as shown in Figs. 1 and 2, are normally used, but double seal assemblies, as in Fig. 3, are recommended where:

(1) High temperatures necessitate the circulation of a coolant.
(2) Leakage of the process fluid must be minimised.
(3) Corrosive or abrasive materials are being handled.
(4) Auxiliary lubrication of the sealing faces is required.

Improvements to the design of the single type of seal are reducing the number of applications for which double seals must at present be specified.

INTERNAL OR EXTERNAL SEALS—Seals mounted within the stuffing box are the type usually specified, but should not be used if the process fluid is abrasive or corrosive. However, new materials now becoming available, including p.t.f.e., are reducing the need for external seals, since it is possible to manufacture internal-seal components presenting completely plastics faces. One type is shown in Fig. 9.

External seals, as shown in Fig. 2, are provided with the rotating sealing face outside the rubbing face. This type of seal can either be recessed into the casing of the equipment or can be completely external.

If there is a limitation on the space available within the stuffing box, it may be necessary to specify an external seal, as there will normally be sufficient clearance outside the casing to fit a suitable seal.

TABLE 1. Seal face materials commonly used together for various applications

Opposing Seal Faces		Process Fluid					
		Water	Petrol	Oils	Caustics	Acids	Brine
Compounded carbon	Bronze	●		●			
	Nickel cast iron	●●	●●	●●		●●	
	Ceramic	●●	●●	●●	●	●●	
	Stellite	●●	●●	●●			
	Tungsten carbide	●●		●●			
	Hard chromium	●●	●●	●●			
	Cast iron		●●	●●	●		
	Stainless steel					●	●●
	Glass-filled p.t.f.e.						
Tungsten carbide	Tungsten carbide	●		●		●	●●
Cast iron	Bronze						
Ceramic	Stellite					●	
Stellite	Aluminium bronze						●

TABLE 2. Selection of seal type for various operating conditions

Operating Conditions	Type of Axial Seal							
	Single	Double	Unbalanced	Balanced	Internal	External	Stationary	Rotating
Normal conditions	●	●	●●	●	●	●	●●	●
High temperature	●	●		●●	●	●	●	●●
High pressure	●	●		●●	●	●	●●	●●
No leakage permitted	●	●●		●●	●	●●	●●	●●
High p/v ratio		●●		●●	●	●●	●●	●●
Volatile fluid		●●		●●	●	●●	●●	●●
Poor lubricating properties	●		●●	●●	●	●●	●●	●●
Corrosive action	●		●●	●●	●	●●	●●	●●
Abrasive content	●			●●	●	●●	●	●●
High-speed shaft	●●	●	●	●●	●●	●●	●	●●
Dry seal face required	●●			●●	●●	●●		●●
Seal chamber size limited	●●			●●	●●	●●		●●
Minimum servicing	●●			●●	●●	●●		●●
To fit existing shaft	●●			●●	●●	●●		●●
Auxiliary lubrication		●	●●	●●			●	

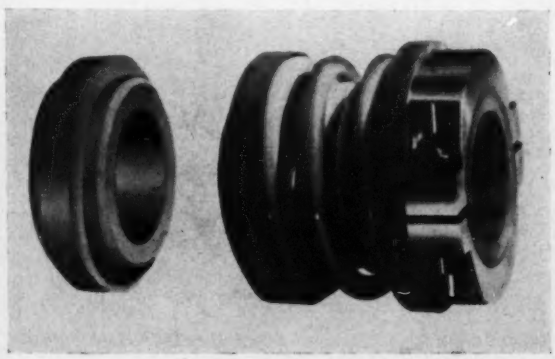


Fig. 9. The Crane Fluoseal is designed for corrosive conditions, and is entirely composed of p.t.f.e. or p.t.f.e.-sleeved components. There are two versions of the design: the type 10 for external mounting, having only one running face, and the type 12, which is double-ended for internal mounting.

Fig. 10. Crane type 14 bulkhead seal, developed for use on drive shafts passing through bulkheads or explosion walls. It can accommodate a high degree of misalignment, and even an explosion would not open both faces.

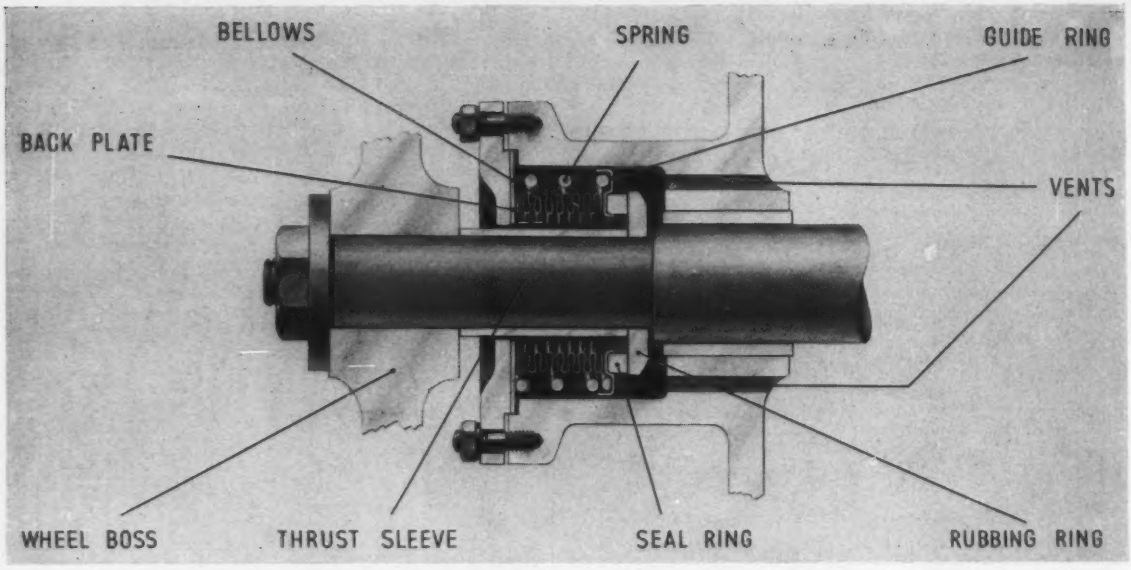


Fig. 11. Typical arrangement of a Teddington packless shaft seal of the stationary type, in which the non-rotating seal ring is joined to the housing by a resilient metallic bellows.

BALANCED OR UNBALANCED FACES—The "balanced" condition of the rotating sealing ring refers to the hydraulic balance of pressure achieved by permitting the process fluid to act with equal force on the two faces of the seal, as shown in Fig. 8. The illustration on the right shows that the pressure spring exerts the only force tending to keep the rings together.

An unbalanced sealing ring is forced towards the rubbing ring by the combined pressure of the spring and the hydraulic force of the liquid.

Modern practice is to design seals having partial balance, with the spring exerting a predetermined force upon the ring, with a small hydraulic force in the same direction.

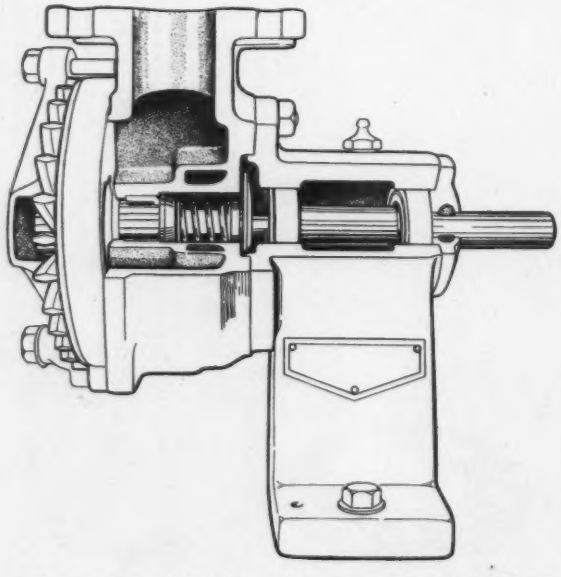


Fig. 12. Typical application of a Romet seal (made by Super Oilseals & Gaskets Ltd.) to a Beresford centrifugal pump. The seal face material that is employed is Monum, suitable for most fluids and gases.

STATIONARY OR ROTATING SEALING RINGS—This factor determines whether the pressure spring unit is to rotate with the shaft, or is to be attached to the stationary casing.

Seals having rotating sealing rings can be fitted to existing equipment more readily than those having stationary rings, since no special machining of the shaft is required. Rotating rings also have the advantage of possessing sufficient centrifugal force to keep the faces free from foreign matter.

Although it may be more expensive to fit, the stationary type of sealing ring has the advantage of reducing the number of rotating components.

Advantages of Axial Seals

Radially-operating seals may be used for low and medium pressure applications, where the properties of the process fluid or gas are not critical. The axial seal should be specified for higher pressures and abnormal conditions.

The advantages of using mechanical axial seals include elimination of wear on shaft; control of fluid leakage; long service life; reduced power absorption; extended period between maintenance checks; ability to compensate for shaft vibration, eccentricity and end play; and optional incorporation of controlled cooling, and flushing of sealing faces in critical conditions.

The latest trend is towards packaged seal assemblies supplied "off the shelf" and installed as a unit. However, these units tend to be expensive, and are not so easily adjustable to individual conditions.

It is anticipated that seal designers will concentrate in the future upon providing a seal which can be as easily installed as the packing material of the common packed stuffing box while retaining the advantages of the axial seal.

British Makers of Axial Mechanical Seals

Burtonwood Engineering Co. Ltd., Warrington, Lancs.
Crane Packing Ltd., Mechanical Seals Division, Slough, Bucks.
Filton Ltd., Clapham Street, Leamington Spa, Warwicks.
Flexibox Ltd., Nash Road, Trafford Park, Manchester, 17.
Super Oilseals & Gaskets Ltd., Birmingham Factory Centre, King's Norton, Birmingham, 30.
The Teddington Group of Companies, Sunbury-on-Thames, Middx.
Charles Weston & Co Ltd., Irwell Bank Works, Douglas Green, Pendleton, Salford, 6.

SIMPLE DRAWING OFFICE SYSTEMS

In an efficiently-run drawing office, references must be traced quickly and easily. This article suggests a simple system for design offices

by F. KINGSMAN, A.M.I.E.D.*

QUALIFIED designers and draughtsmen are so scarce these days that it is an unusual drawing-office where all members of the staff can be regarded as permanent. When the high cost of a designer's time is considered, the accepted settling-in period of new staff becomes a costly investment. The settling-in process is really the time spent in learning what system is in vogue, finding where the drawings and catalogues are kept, knowing the company's range of products, and so on.

Every drawing-office has its own means of storing the various documents with which it works. Suppliers' catalogues may be kept in one place, filed according to this method. The company's own catalogues of products are filed elsewhere, often in no system at all. Correspondence is in these cabinets filed to this system, parts lists over there filed to that system, and the drawings entered in a thick volume, or even several volumes. This is all explained to the new-comer, who is baffled from the moment the explanations begin, and the reason for his confusion is that each type of information is treated in a different way.

Basically, the difference between a drawing and a catalogue is one of form, and this cannot be changed; but the contents of both may be identical. This, then, is where an attempt can be made to treat all the different documents in the same manner.

If each paper, whether drawing or catalogue, part list or performance curve, correspondence or complaint report, is classified according to a simple system, then the new-comer needs to know only the appropriate classification number—and an alphabetical card index provides most of the remaining information.

To give an example of the method, let the case of a company of general engineers be considered. The classification chart (Table 1) is divided into eight main categories, each covering a group of the company's products.

The fairest way to see how the method works in practice is to follow the progress of a new-comer facing these conditions. He is handed a chart and it is suggested that he finds all the data possible on, say, plastics mixers; quite rapidly, the classification number concerned is found to be 64. The footnote on the chart gives certain code letters denoting where the information is stored. Knowing the location of the catalogue shelves, it is easily seen if any 64X catalogues are filed there. Next on the list are the

ALFRISTON ENG. Co. LTD. CUSTOMER
125 Barrow Vale, London, S.W.19

Item	*Parts List No.*	*Date Installed*
PLASTICS MIXER	64E6021A	21.6.57

Fig. 1. Specimen card for customer's records, giving drawing number and other desired information.

64 PLASTICS MIXERS.

Capacity	*Voltage*	*Hand Controls*	*Parts List No.*
100 lb.	400/440	RH	64E2986 A
	380	RH	64E2986 B
	400	RH	64E2986 C
	(Brooke Motors) 400/440	LH	64E2986 D
250 lb.	400/440	RH	64E3061 A
	400/440	LH	64E3062 A
	400 D.C.	RH	64E3061 B

Fig. 2. Card for company's products, giving details of parts list number.

911 PINS: STAINLESS STEEL

All pins up to $\frac{1}{4}$ in. dia. to be made from F.D.P. ground bar wherever possible. Over $\frac{1}{4}$ in., use black bar and grade of stainless which is suitable for application. For data, see 981 classification.

Stainless-steel pins must not run in a bush of a similar grade, of stainless steel or seizure will occur: see notes in 981 section.

Fig. 3. Method of recording information in words about a component and its use.

911 PIN $\frac{1}{4}$ IN. DIA.—HEADED

Drg. No. 911A487 MS

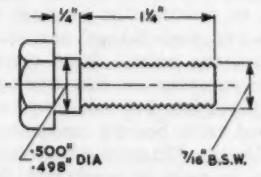


Fig. 4. Diagrammatic record on a filing card of a component.

* *Chief draughtsman, Pelkman Bros. Ltd.*

COMPANY PRODUCTS

10 FANS, BLOWERS, PUMPS	20 CONVEYORS	30 PNEUMATIC MACHINES	40 FURNACE EQUIPMENT	50 DIE-CASTING MACHINES	60 PLASTICS MACHINES	70	80
11 Centrif. fans	21 Gravity roller	31 Hammers	41 Oil-fired units	51 Mk. I	61 2½-in. extruders	71	81
12 Axial flow fans	22 Slatband monoplanar	32 Moulding machines	42 Gas-fired units	52 Mk. II	62 5-in. extruders	72	82
13 Positive displt. pumps	23 Slatband biplanar	33 Sand sifters	43 Coal-fired units	53 Mk. III	63 Pelleters	73	83
14 "Tich" blowers	24 Screw type	34	44	54	64 Mixers	74	84

ENGINEERING COMPONENTS

910 POWER TRANSMISSION	920 MECHANISMS, SPRINGS AND LINKAGE PARTS	930 MEANS OF SECURING AND LOCATION	940 PIPING, PIPE FITTINGS, etc., LUBRICATION	950 CONSTRUC-TIONAL COMPONENTS	960 ELECTRICAL INSTRUMENTS	980 TECHNOLOGY, PROCESSES, D.O. SYSTEM	990 MATERIALS
911 Pins Shafts	921 Drums Rollers Wheels	931 Spacers (solid and hollow) Washers Collars	941 Lubricants	950 Drilled plates Gussets Fishplates	961 Motors	981 Welding Heat treatment	991 Ferrous materials Semi-finished products
912 Hubs	922 Cams Eccentrics	932	942 Nipples Cups Lubricators	952 Drilled angles Channels Cleats	962 Switch-gear Circuit breakers	982 Data on workshop technology	992 Non-ferrous materials
913 Bearings and housings Thrust washers	923 Links, Levers Fork ends	933 Tie-bars Screws Studs	943 Seals Oil-retainers	953 Stools Brackets	963 Solenoids Relays	983	993 Rubber Plastics Textiles
914	924	934 Proprietary fastenings Lindapters	944 Special pipe-fittings	954	964 Condensers Resistors	984 Employees Welfare Safety, etc.	994 Concrete Insulating materials

NOTE how this system provides for future expansion, both vertically and horizontally.
A complete reference is made up of the classification number, plus a code letter, plus (if necessary) a serial number from the D.O. register.

Example	*Typical Ref.*
Bulky catalogue or book	64X
Flimsy catalogue or any paper other than a drawing	64Z
Stranger drawing	64W 1191
Drawing sheet size 10 × 15 in.	64A 1192

Drawing sheet sizes: A = 10 × 15 in.; B = 15 × 20 in.; C = 20 × 30 in.; D = 30 × 40 in.; E = sizes larger than D.

thinner catalogues which come within the category 64Z, and their filing cabinet (preferably the suspended pocket type) is indicated. On opening the appropriate drawer, it is apparent that 64Z items are spread over two pockets, one with a yellow tab containing catalogues only, and one with a red tab containing letters (or résumés where considered desirable), performance curves, reports, and data sheets. There is nothing to stop these being again separated out if desired, of course, but all bear the reference "64Z".

At this stage the new-comer is shown the card index cabinet. In one drawer of this is a collection of makers' names cards. Each card of a suitable size records the classification number of the maker's catalogue and other useful information.

Another similar drawer is maintained for customer's records (see Fig. 1). A third drawer—classified subjects (Fig. 2)—provides the key to drawings and parts lists. Each drawing possesses its own record card, on which is quoted sufficient information to enable a decision to be made whether or not the relevant drawing is at that moment of interest. This information may be in words or as a hand-sketch (see Figs. 3 and 4); each list not incorporated into a drawing also has its card. From these cards it is possible to find a block of classification 64 cards which represent all the drawings and parts lists of, say, plastics mixers.

Obviously, over the years a large number of class 64 cards come into existence, so that finding one particular one can be a tedious job; but it is simple to subdivide the block with tabbed cards bearing convenient headings such as "Complete Units", "Framework Details", and so on.

At this point is must be explained that components which occur over and over again in engineering—chain-wheels, V-pulleys, angle cleats, bushes, and so on—are separately classified in section 900.

By doing this, items of greatest utility are collected together and a range of parts created which is suitable for the modern approach to rationalisation. Whenever a new part is drawn (the index first having been consulted to see if a suitable part already exists) it must be decided if the part is to be classified in the 900 group. The criterion should be the likelihood of the particular part being used again on a rather different assembly or machine; if this is so, then the 900 group is chosen, and this choice at once implies that the part conforms to some high standard of usefulness. In a chainwheel, for example, the tooth form would be to suit a B.S. chain and the proportions of the boss would agree with an accepted commercial item. The bore size and limits, and the keyway, would be to a practice accepted within the company. Thus the item would be standardised, for any feature varying from or additional to those mentioned would make the item a "special" and not likely to be used on another machine; and, as such, not classifiable within the 900 group.

It may be a company's policy to restrict the range of parts within the 900 group. For example, 8-mm. and ¼-in. pitch chains may not be used, and suitably written cards in the appropriate index sections will reveal this policy.

Again, a preferred range of parts may be decided upon. This can be again exemplified by chainwheels, for it is common knowledge that such a range of tooth numbers as 19, 21, 25, 38 and 57 will provide most of the chain drive ratios in common use. These preferred parts can be brought out of the group of standardised parts by putting them in a suitably marked portion of the index in front of the remainder of their group.

If the policy brings about the results expected, then it

would be natural to keep certain items of the preferred range always in stock. These stock items would have their cards suitably marked, and it would be usual for these cards to be selected in preference to non-stock items, other things being equal.

Turning now to a new drawing (which has been classified as, say, 64), it will have been drawn on a particular size drawing sheet—perhaps 15 in. × 10 in. which is known as an "A" size in the firm chosen as an example. The drawing also has a serial number taken from the D.O. register; thus the drawing number complete will be 64A9651.

If this particular drawing had been an assembly, then it is suggested that the parts list number should be the same as the drawing number, whether or not the parts list is ruled up on the drawing itself.

Drawings originating outside the company, and often called "stranger" drawings, are classified exactly as the previous example, but distinguished from it by the use of a letter W. Thus drawing 64W9652 is a stranger drawing, filed in numerical order in the same drawer as other such drawings, partly because there are not many of them and partly because they come in all shapes and sizes.

The company's own drawings would be filed in plan chests and there may be one labelled "64" with its drawers partitioned to accommodate the various sizes of drawing. In the majority of drawing-offices it is usual for a section leader and his men to be responsible for one category of the firm's products. The 64 plan chest will, therefore, automatically come under the care of a particular section leader and be located conveniently to hand. The 900 plan chest will, of course, occupy a more central position in the office.

It is not difficult to appreciate how readily this method can affect the office's relationship with the works. It can become common for a voice on the telephone to refer simply to "drawing 64A9651". The mere repetition of this number aloud by the D.O. clerk can alert the appropriate section leader; the sheet size of the drawing has automatically been quoted and the drawing is quickly located either in its drawer, or by reference to the drawing registration slip filed in the place of the missing drawing to show who has taken it and where it is.

Once a drawing has been issued by the D.O. to the works, the classification number continues to be of use, for the present-day tendency is that individuals specialise in groups of products, and, therefore, a class 64 drawing will automatically reach one particular section of the planning department, and similarly in other sections.

It is common practice for stock control department to group all the parts of a machine in one volume of their records, with the exception of certain common items. Classifications 64 and 900 will provide a tailor-made means of doing this, of course, and the process extends itself to the finished parts stores.

The erecting shops tend to specialise in the assembly of particular products. Thus the very existence of a classification number on a document ensures that it is routed to its correct destination, and the finished parts to the correct stores or erecting bay.

Sales and accounts departments also are affected; a spares order from a customer will list, in effect, classification numbers enabling the price records to be speedily turned up, and the paper-work correctly routed.

The method, which is an amalgam of systems frequently met with in drawing-offices, can be summed up as a method of finding information which has been filed by subject classification according to a simple chart, the form of the information being secondary. The subject classification is of utility throughout offices and works and forms the basis of a consistent system for parts and paperwork alike.

A NEW PLANT FOR HEAT TREATMENT

WITH the ever-constant demand for metals with improved properties in one or more directions, the metallurgist is always facing the problem of how best to achieve these, whether it be by alloying with different materials or changing their proportions, by cold working, purifying, heat treating or by any of the other many variables.

Whatever the method, it is increasingly obvious that accurate control of the process is absolutely necessary and this in many cases demands new and sometimes expensive equipment to ensure that this control is strictly maintained. The heat treatment of basic metals and components is no exception.

Alive to this fact, Firth Derihon Stampings Ltd. have recently installed a new heat-treatment plant at their Darley Dale works. The commissioning of this new heat-treatment plant, comparable with any installation in Europe, reduced the labour force required by 50 per cent and the maximum number of heat-treatment furnaces in operation by 75 per cent.

The new plant fulfils the need for much greater accuracy of heat-treatment procedure to deal with a daily range of highest quality carbon steels and alloys, nickel-based and titanium alloys, together with the desire to reduce maintenance of the plant. All furnaces are fired from the town gas supply and necessitated the laying of a twelve-mile-long, 15-in.-diameter high-pressure gas main. Each of the three Gibbons Duel-system heat-treatment furnaces, capable of handling loads up to 5 tons, are 11 ft. long, 6 ft. 6 in. wide with a height of 3 ft. 3 in., and have normal operating temperature ranges of 200-750 deg. C. with forced recirculation and 750-1,250 deg. C. without forced recirculation. The temperatures are electronically controlled by a fully-automatic electro-pneumatic system, the Honeywell-Brown control instruments being housed in a centrally-positioned control room.

The two tempering furnaces, of the same size as the heat-treatment furnaces, are two-zone controlled and the temperature distributed throughout each of the furnaces is held to extremely fine limits, being indicated and recorded at any six points in each furnace. All are fully instrumented and controlled to safeguard against failure.

The actuation of the air pressure compressor units for the pneumatic control equipment is automatically controlled via the instrument room. The oil quenching machine is of fully-enclosed type with automatic door operation. The lowering and lifting of the load and the variable controlled oscillation during the quench period are also automatic. The cooler for the oil is capable of dealing with 27,000 gallons of oil per hour, using 12,000 gallons of water per hour.

The accurate control needed in heat treatment is not only inherent in the design of the actual equipment, but must also be present in the overall layout of the plant to ensure the controlled cycle of operations involved in any heat-treatment operation.

For this reason the general layout of the plant will handle large and small batch production of a wide range of forgings varying in weight from a few ounces up to 800 lb. eliminating as far as possible all manual handling.

BONDING METALS WITH THERMOSETTING ADHESIVES

Reduction of weight and cost are particular advantages offered by resin adhesives for bonding metals. This article discusses the merits of this technique in relation to conventional methods

by E. J. CATCHPOLE, B.Sc. (Eng.), A.F.R.Ae.S., M.I.A.S.*

A THERMOSETTING resin is defined as one which hardens by the application of heat or through the addition of catalysts, or by both means, as the result of an irreversible chemical change; thereafter, the resin usually remains substantially infusible and insoluble. Thus, thermosetting adhesives can be, and often are, capable of being set at room temperature, though more frequently the structurally-reliable adhesives are cured at temperatures between 100-250 deg. C. Generally speaking, the properties of even the cold-setting adhesives are improved by the application of heat; this is in addition to the increased rapidity of bonding which results.

One of the important advantages of a thermosetting resin over a thermoplastic resin is that it can frequently be cured at temperatures below its operating temperature; for example, hot-setting phenolic resins cured at 150 deg. C. may retain their strength up to 250 deg. C. or more (see Fig. 1).

Unfortunately, although for some purposes unmodified thermosetting resins of this type may be used, it is often necessary to add other constituents with a view to obtaining all-round performance. In particular the phenolic resins, and to some extent the epoxies, tend to be brittle and may be much improved by the addition of a more resilient second constituent. For many structural applications it is important to obtain a resilient bond (particularly with aluminium alloys which may undergo considerable deformation before failure) and therefore phenolic resins for this purpose are usually modified with rubber or with a polyvinyl acetal.

If an appreciable proportion of thermoplastic constituents is included, one advantage of the thermosetting adhesive mentioned above, namely, service above its curing temperature, is lost, but nevertheless the advantage of resistance to solvents which results from cross-linking during curing may be maintained. A further step is made when the thermoplastic constituent becomes the major part of the adhesive, for example, in the nylon-phenolic adhesives discussed later. In these, the thermosetting component is only used because of its good wetting properties and the main part of the bond consists of thermoplastic nylon. The chemical nature of nylon makes it resistant to most solvents and, provided that full melting of the nylon takes place, a good resilient durable joint is achieved.

* *Manager, bonded structures division, CIBA (A.R.L.) Ltd.*

Thus it will be realised that, although it is mainly thermosetting resins that are being discussed here, it is impossible to ignore thermosetting/thermoplastic mixes when considering the practical aspects of bonding.

Types of Adhesive

Modified polyester adhesives have been used in metal-to-metal bonding, but generally they are not sufficiently strong or resilient and their shrinkage on setting is a strong disadvantage. Recent work in Germany, however, has suggested that vinyl-modified polyester resins may be suitable is certain specialised applications—and in particular where the adherends are rigid and peeling is prevented by the addition of bolts. Epoxy resins have been used with some success for the bonding of primary aircraft structures. They have the advantage of being capable of curing without pressure, but frequently the disadvantage of a rather low peel strength which is particularly significant in thin metal structures. For aircraft flying subsonically epoxy resins have therefore been less widely used than other types, but they are again coming into their own for high service temperatures.

The most important adhesives for metal bonding in aircraft are therefore those based on phenolic resins, and the most important modifiers are the polyvinyl acetals and various rubbers. The effect of various modifiers on shear strength is shown in Fig. 2.

At least one phenolic-polyvinyl formal adhesive has been used widely in metal aircraft structures since the middle of the last war. Its development was a most important step; for bonding porous adherends such as wood, solvents may be included in the resin, since they are absorbed by the adherends, but in metal bonding it is necessary to dry off all solvents before closing the joint. Film versions are now also made, both for metal-to-metal bonding and for honeycomb sandwiches. The films have the advantage of being simple in application over large areas and in controlling the amount of adhesive and the ratio of phenolic resin to polyvinyl formal. The two-component form is still very widely used, however, and it is particularly suitable for bonding complicated shapes.

Performance of Bonded Structures

WEIGHT REDUCTION—Elimination of the weight of the rivets is, of course, a factor in weight reduction, but much more important is that bonding allows the skin structure

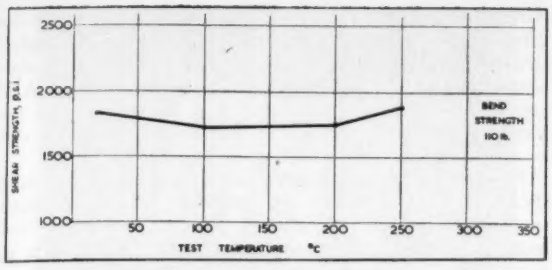


Fig. 1. Strength/temperature relationship of an unmodified phenolic resin cured at 150 deg. C. Alloy: 24 ST.

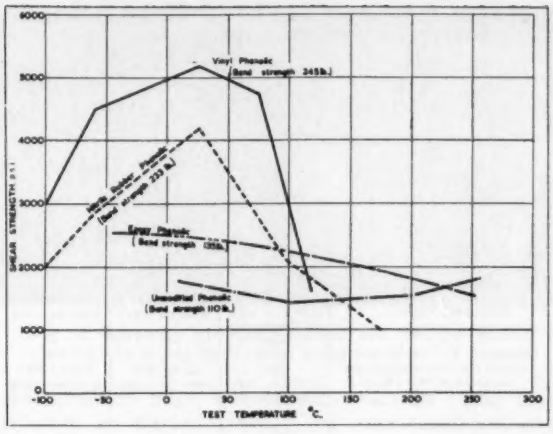


Fig. 2. Strength/temperature relationship of phenolic-based adhesives.

to be stressed more completely, and hence allows thinner material to be used to carry a given load.

For instance, in an aircraft wing where the skin is bonded to longitudinal stringers, wrinkles are suppressed under load. In the case of riveted construction, the stringers and skin work much more independently and therefore buckle at a lower stress. Thus the influence of rivet pitch and diameter on the strength does not arise in bonded panels, and more accurate calculation of failing loads is facilitated. This is a further distinct advantage when designing bonded structures.

The weight advantage in using bonding covers many different types of panel. Panels tested over a range of strut lengths by the N.L.L. in Holland all showed a considerable strength gain from bonding, and Fig. 3 shows the results of some tests by the SAAB company in Sweden on various bonded elements.

Properly bonded panels can demonstrate remarkable bond tenacity under test. For example, in some of the panels whose test results are shown in Table 1, the stiffeners were very severely distorted, but all the glue lines remained intact.

FATIGUE STRENGTH—This is greatly increased and general behaviour under fatigue loads much improved. Bonding distributes the load uniformly over the entire area of contact between the parts being joined, and thus local stress concentrations around rivets or spotwelds are eliminated.

In considering fatigue behaviour, the performance is categorised under (a) safe life and (b) fail safe. Approach (a) assumes that the important thing is to guarantee a certain safe life, whereas (b) says that it is, if anything, more important to ensure that any early failure can be detected before it reaches catastrophic proportions.

As van Beek[1] has pointed out, there is less difference between these two approaches than one might think. In particular, bonding ensures greater safe life than riveting, and it has also the remarkable property of ensuring a much slower propagation of fatigue cracks than in either riveted or integrally stiffened structures. Fig. 4 shows the results obtained by the N.A.C.A. in the U.S.A. on designs with riveted stiffeners, bonded stiffeners and integrally machined stiffeners. In these tests the rate of propagation of the crack after initiation was measured and it is seen that the bonded construction shows a much lower rate of crack propagation than either the riveted or integral panels. This is a finding of great significance.

PRODUCTION COSTS—The actual saving is very much dependent upon the type of structure. Where the total bond area is small, the process may not be cheaper, but with correct design for bonding, large areas and large numbers of parts can be bonded in one operation. It will be understood that the cost of bonding is far less dependent upon the total area to be joined than it is with other forms of fastening such as riveting and welding. In one of the Fokker Friendship wing panels, containing sixty-four parts, all the bonding is done in one operation; the saving in a case like this is obvious. For commercial work, the following figures comparing the material and labour costs of one set of riveted and bonded lorry dropsides and tailboards made by the Northern Aluminium Co. are of interest:

	£	s.	d.
Riveted			
1,250 $\frac{3}{16}$-in. "Pop" rivets	3	1	3
Labour: 8 man-hours at 15s.	6	0	0
TOTAL	£9	1	3
Bonded			
Materials, depletion of degreasing and pickling baths		3	0
$\frac{1}{4}$ lb. Redux liquid K6		2	6
$\frac{1}{8}$ lb. Redux powder C		3	5
Labour: 2$\frac{1}{2}$ man-hours at 15s.	1	17	6
TOTAL	£2	6	5

TABLE I. Results of Fokker shear panel tests

Panel	Thickness (in.)	Stiffener thickness (in.)	Stiffener spacing (in.)	Height of web (in.)	Ultimate Shear Stress		Material
					riveted p.s.i.	bonded p.s.i.	
I	0·032	0·040	5	10·5	20,700	23,900	24 ST
II	0·040	0·032	3	18·0	12,400	15,100	24 ST
III	0·060	0·048	3	18·0	25,400	29,800	75 ST
IV	0·032	0·032	6	18·0	8,500	9,100	24 ST

TABLE 2. Performance of Hidux 967 and 1033 high-temperature adhesives, compared with U.S. spec. MIL-A-8431, type I

Test	Spec. Requirement (p.s.i.)	Hidux 967 (p.s.i.)	Hidux 1033 (p.s.i.)
Short-time shear			
At −55 deg. C.	2,250	4,700	4,100
At 20 deg. C.	2,250	5,000	3,500
At 149 deg. C.	2,200	3,400	2,900
149 deg. C. Shear strength after 192 hr. at test temperature	2,000	3,300	2,600
Normal temperature fatigue—strength at 10 million cycles	600	Over 800	Over 800
Normal temperature creep rupture strength and deformation for 192 hr.	1,600 (0·015 in. max. total deformation)	Over 1,600, with no creep	Over 2,000, with no creep
149 deg. C. Creep rupture strength and deformation for 192 hr.	800 (0·015 in. max. total deformation)	Over 800, with no creep	Over 1,000, with no creep
Normal temperature bend strength	130 lb.	240 lb.	180 lb.

EXTERIOR FINISH—The absence of rivets in itself improves the surface finish, but, in addition, buckling of panels takes place at (i.e., smoothness is maintained to) a higher load.

LEAKAGE RESISTANCE—Sealing of pressurised cabins or integral fuel tanks is much simplified, since good structural adhesives are highly resistant to air and fuel leakage.

FREEDOM OF DESIGN—The designer has considerable freedom in reinforcing the structure wherever required, and riveting design problems are eliminated.

EXAMPLES OF BONDED COMPONENTS—Already, in the United States a number of structural adhesives have been used in recent years, but, with the exception of honeycomb sandwich structures, bonding has mainly been confined to secondary applications. Certainly, the advanced and extensive uses of resin bonding by the de Havilland and Fokker companies, for example, far surpass anything done outside Europe in the field of metal bonding. Recently, the Fairchild company has followed the example of Fokker in using a British adhesive for bonding the F27 aircraft.

While the most advanced and interesting uses of metal bonding have been in aircraft, there have also been some promising commercial applications.

Entirely successful bonding can be effected between metal and various other materials, notably wood, rubber and friction linings.

Metal-wood bonding was used by the de Havilland Aircraft Co. on the Hornet wing in 1943, its use being the first example of the bonding of metal in primary aircraft structure; no failure was ever reported. Since then metal-wood bonding has been used for a number of commercial applications. Once a thin veneer has been bonded to the metal, assembly to the rest of the wooden structure can be made with normal wood glues.

Friction linings are bonded on a large scale to brake shoes and clutch plates. A material which has been specially developed for this purpose is Redux 64, and millions of shoes have been successfully bonded with it, two notable European users being Daimler-Benz and Citroen. Bonding has a number of advantages over riveting for drum brakes, the main one for the consumer being longer life. The development of disc brakes is almost entirely dependent on the use of adhesives.

Disc brakes rely to a very large extent on the use of adhesives. While riveting still survives in some drum brakes, the mode of attachment of the disc brake liner to its backing plate is considerably more critical. When the liner heats up due to braking, there is a strong tendency for it to distort, and mechanical fastenings would allow the edges to lift, so that only a portion of the liner was in contact with the disc; a strong high-temperature-resistant adhesive, however, holds the liner rigidly to the backing plate even under these severe conditions. The accurate mating resulting from bonding the lining to the backing plate also allows a small clearance between the liner and the disc, thus facilitating small pedal movements.

One of the earliest production cars to employ bonded disc brakes was the Citroen DS 19.

High-temperature Adhesives

Much effort is being devoted, especially in Britain and the U.S.A., to a search for adhesives suitable for bonding metals for "high-temperature" service.

First, it must be seen how the need for a high-temperature adhesive arises and thus define what is meant by "high-temperature" in this context. The need for high-temperature adhesives for metal bonding in aircraft arises from the so-called "heat barrier" encountered in supersonic flight. Flight at twice the speed of sound, even at high altitude, leads to skin temperatures of the order of 100 deg. C., flight at three times the speed of sound means about 300 deg. C., flight at four times the speed of sound means about 500 deg. C., and so on. Corresponding to these temperatures, a change of materials, probably in the sequence aluminium/titanium/steel, is demanded. (Due to high cost and difficulties of fabrication, titanium may be omitted from this sequence.)

Thus, the demands on the adhesive are for ever-increasing service temperature and for bonding titanium and

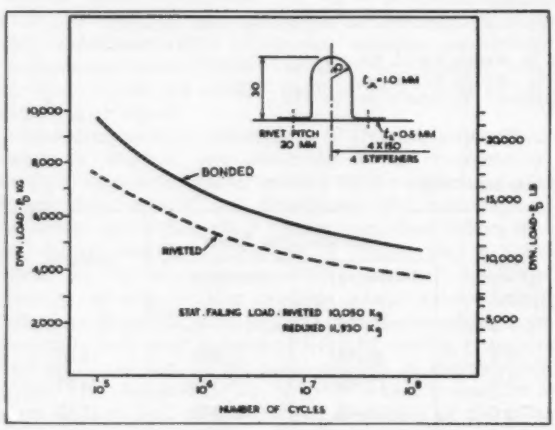


Fig. 3. Comparative results of fatigue tests upon riveted and Redux-bonded panels with top-hat stringers.

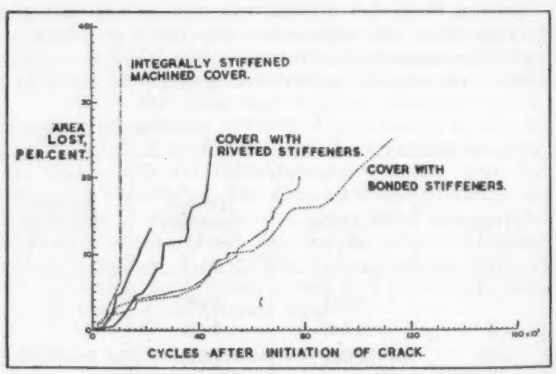

INTEGRALLY STIFFENED MACHINED COVER.
COVER WITH RIVETED STIFFENERS.
COVER WITH BONDED STIFFENERS.
AREA LOST, PERCENT.
CYCLES AFTER INITIATION OF CRACK.

Fig. 4. Fatigue crack propagation in various types of stiffened panels.

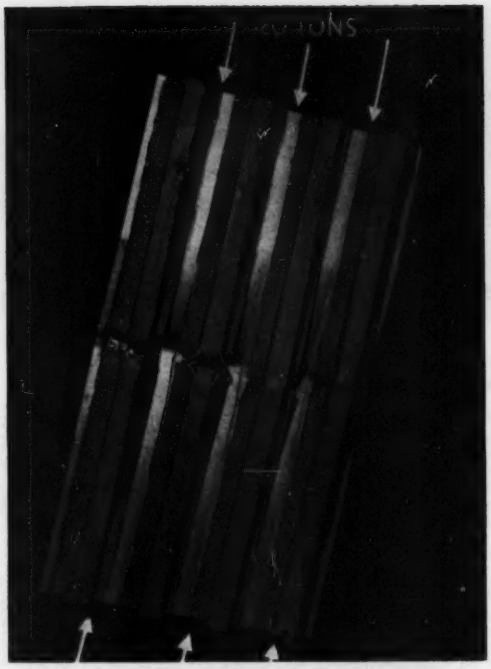


Fig. 5. Test panel with bonded heavy-gauge top-hat stringers which, under a stress of 120 tons, has exhibited an explosive type of fracture in the metal before failure of the bond.

steel. The bonding of titanium and steel can quite successfully be accomplished using special pretreatments, but, so far as the temperatures are concerned, increasing speed can soon elevate the demands to the impossible so far as organic adhesives are concerned, leading to the investigation of ceramic adhesives, for example. However, the more immediate first step, which can be achieved with organic adhesives, and which probably covers many applications for aluminium alloys, it to formulate a suitable adhesive for long-time service at about 150-200 deg. C. Here the problem mentioned earlier—that of formulating a resilient adhesive—becomes much more severe. The adhesive must be modified to reduce brittleness without reducing its strength at high temperatures so drastically as is the case if a polyvinyl acetal or rubber is used. As is seen in Fig. 2, quite good shear strengths may be obtained in this temperature region by using an epoxy-phenolic combination, but the bend strength (tested as in U.S. Specification MIL-A-8431 and shown in Fig. 2) is rather low, that is to say, the adhesive is rather brittle.

Two approaches to this problem have been adopted by CIBA (A.R.L.) Ltd. One was to find a modified epoxy resin with suitable heat resistance; the resulting adhesive is known as Hidux 1033. It has good strength even above 150 deg. C., and it does pass the "bend test" by a considerable margin; the curing cycle is 140 deg. C. for 40 min. The second was to use nylon films as hot-melt adhesives. A thermosetting phenolic resin is used as a primer, otherwise very poor results are obtained. This nylon and primer (Hidux 967) behave well in the 150 deg. C. region. Table 2 shows the performance of these adhesives in relation to MIL-A-8431.

This type of adhesive has the great advantage of being very resilient, and that it also exhibits a high shear strength. The chief difficulty in application is that high curing temperatures are required; in the case of Hidux 967, it is 220 deg. C., though it is only necessary to maintain this temperature for two minutes. For the sake of

Fig. 6. Examples of Hidux-bonded and riveted panels showing the failing loads under compression at 150 deg. C.

the aluminium alloy, it is necessary that the curing temperature be reached quickly, the cure completed, and rapid cooling applied; it is also important that the phenolic resin should not cure off before the nylon melts. Virtue can be made out of these necessities by designing special equipment, or adapting existing equipment, to give very rapid production of bonded parts.

Two types of curing fixture have been developed for bonding with these materials. In the first, electrically-heated and water-cooled pressure bars are used to cure top-hat stringers on to a skin. The pressure bar temperature is set to 225 deg. C.; this is maintained for two minutes, after which the power supply to the heaters is switched off and the cooling water turned on. After about one further minute (five minutes total cure cycle) the glue-line temperature is down to below 170 deg. C. and the panel is removed from the jig. The results of testing such a panel at 150 deg. C. are shown in Fig. 6, a comparison being made with an otherwise identical riveted panel tested at room temperature. For this particular configuration an increase in strength of about 50 per cent was shown.

In the second type of bonding fixture, non-metallic heating elements made by Hunting Mhoglass Ltd., are used. These are embodied in a glass-cloth epoxy resin laminate. The heating laminates are then mounted on suitable packing-up cores (again, an epoxy casting resin, this time with an aluminium powder filler). Again a total cure cycle of about five minutes is achieved.

It does appear that these adhesives therefore are not only attractive in their high temperature resistance, but also from the point of view of rapid production.

It may be seen therefore that the main advantages of bonding are reduced weight for a given load, increased fatigue strength, simplified design, a smooth exterior finish and, in many cases, reduced production costs.

Successful application of adhesives demands great care in the preparation of the parts to be joined. The recommended procedure in bonding metals will be discussed in a further article covering pretreatment, the application of heat and pressure, and the control of quality and inspection of joints.

1. van Beek, E. J. "Design Aspects of Bonded Structures", *Flight*, October 25, 1957.

BIBLIOGRAPHY

de Bruyne, N. A., *et al. Structural Adhesives.* (Lange, Maxwell & Springer Ltd.) 1951.

Bonded Aircraft Structures. (CIBA (A.R.L.) Ltd.)

A.R.L. Technical Notes Nos. 117, 167, 165, 154.

Hardrath, H. F., *et al.* "Fatigue Crack Propagation in Aluminium Alloy Box Beams", N.A.C.A. Technical Note No. 3856.

Northern Aluminium Co. Ltd. Technical Memo. No. 21, 1955.

Forcht, B. A., "Bonding Magnesium", *Aircraft Production*, April 1958, 134-40.

Povey, H. "Press Bonding", *Aircraft Production*, August 1957, 327-36.

Evans, N. "Autoclave Bonding", *Aircraft Production*, June 1957, 240-9.

Johnson, R. A. "Bonding Brake Linings", *Automobile Engineer*, June 1951.

Powis, C. N. "High-temperature Adhesives", *Aircraft Production*, March 1958, 88-92.

The author wishes to express his thanks to those other members of the staff of Ciba (A.R.L.) Ltd. who assisted him in the preparation of this article.

HEAT INSULATION WITH ALUMINIUM FOIL

Present-day problems of heat transfer control have revealed new uses for aluminium foil. This article describes some of the unusual applications in which the material is of special value

RECOGNITION that aluminium foil is capable of reflecting 95 per cent of radiant heat is apparent not only by the increased use in its own right but by its wider adoption for laminating to other insulating materials.

Foil is flexible enough to be used in any type of construction, either in buildings or general engineering applications. Gauges from 0·009 mm. to 0·025 mm. are used for single or multiple laminations with bitumen, glue and other special adhesives to various papers and boards, both corrugated and plain. Laminations are also made to acetate waddings (0·009/10 mm.), expanded polystyrene (0·009/10 mm.), expanded synthetic rubber (0·009/10 mm.), glass wool (0·040, 0·060 mm.), plaster boards (0·009/10, 0·012, 0·018 mm.), plywood (0·009/10 mm.), rockwool (0·050 mm.), and roofing felt (0·012 mm.).

STANDARDS AND CONVERSION—Aluminium foil is produced to British Standard 1470 S.I.C., which gives a purity standard of 99 per cent minimum aluminium with a limitation on impurities of:

Copper:	not more than 0·10 per cent
Silicon:	not more than 0·5 per cent
Iron:	not more than 0·7 per cent
Manganese:	not more than 0·1 per cent

A higher purity aluminium of 99·8 per cent and 99·99 per cent is used for some electrolytic condenser work.

The definition of foil—stated as a maximum thickness—varies in different countries. In the U.K. it is considered to be foil when of a gauge up to 0·15 mm. In France the limit is 0·2 mm., Italy 0·05 mm., Sweden 0·04 mm., and although generally the metric system is used for expressing gauge, in America it is frequently stated in inches—the limit being 0·006 in. Between manufacturers and users a conversion table (Table 1) with appropriate covering areas per unit of weight is useful for avoiding misunderstanding.

PRODUCTION OF FOIL—Cast rectangular slabs of aluminium are reduced 90 per cent by hot rolling, cold rolling to 0·45-mm. strip, and subsequently annealed. This coiled strip, referred to as foil stock, is further reduced by cold rolling to produce foil (Fig. 1) which can be delicately thin at 0·0045 mm.—some ten times thinner than the human hair.

The final pass through the rolling mills of foils below 0·030 mm. is made with a double web feed (Fig. 2), i.e., two reels are fed into the mill simultaneously with a volatile spirit dropped between the two plies prior to rolling. This results in the foil leaving the roll contact surfaces bright and the inner surface matt. After separation of the plies and re-winding, final annealing removes residual oils and sterilises the foil surface in addition to providing the required temper.

Aluminium foil is produced in the U.K. up to a maximum width of 40½ in. The total annual production is currently at the rate of about 22,000 tons.

INSULATION—The control of heat transfer is conditional upon a number of factors, including the direction of heat flow, the materials bounding the area and the degree of heat. Common to most situations is the fact that considerably more than half (in some cases as much as 80 per cent) of the heat transfer across air spaces takes place by radiation. Highly reflective metallic surfaces can, therefore, retain radiant heat inside a building when it is cold outside or reflect solar heat to keep the inside cool.

The insulation spaces are subdivided into pockets of air by lightly crumpling sheets of foil or by making parallel air layers with flat sheets separated by distance pieces. The high reflection and low emission of radiant heat from the foil surfaces prevent heat transfer through the insulation space. Used externally as a roof capping, foil pro-

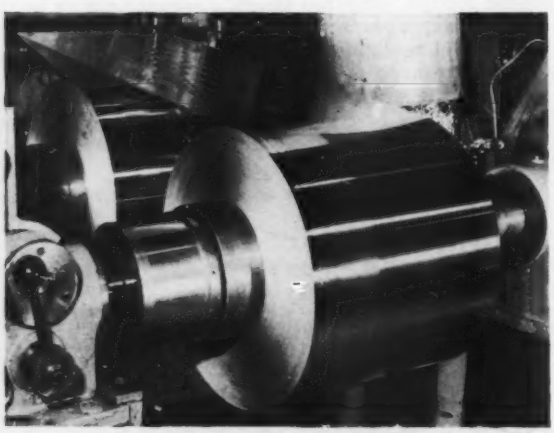


Photo: Star Aluminium Co. Ltd.

Fig. 1. Double rolling of aluminium foil to finished gauge.

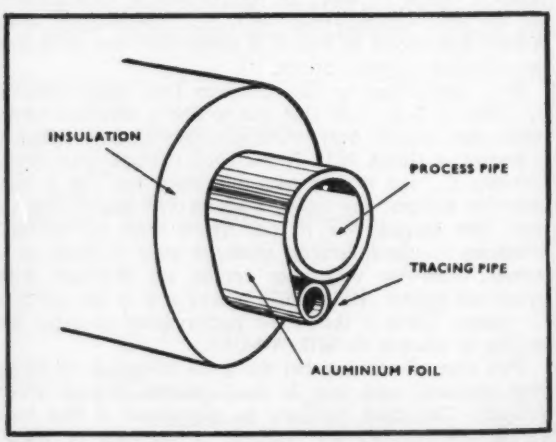


Fig. 2. Experimental use of aluminium foil to prevent exterior insulation coming between tracing pipe and process pipe.

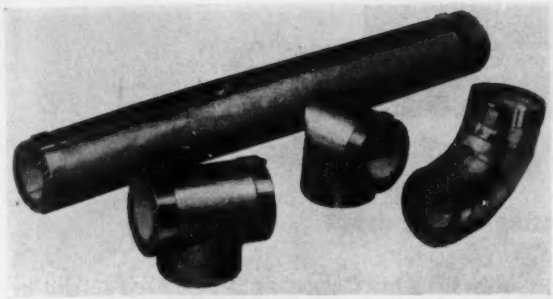


Fig. 3. Cellular asbestos sectional pipe insulation (by Bells Asbestos) with foil.

Fig. 4. *Right.* Jet pipe of the *Bluebird*, world record-breaking speedboat, cut away to show construction of foil insulation.

tects itself against attack from aggressive elements in the atmosphere by the oxide film which forms on the surface.

A simple test demonstrating the reflectivity of radiant heat by aluminium foil may be effected by holding a sheet of ordinary household cooking foil close to, but not touching, the face. The metal will be cold enough so that the major flow of heat will be from the surface of the face to the foil sheet; yet, instead of becoming cool, the cheek will soon feel warm. The cheek, like the body and the surfaces of most ordinary materials, emits or radiates heat at a high rate but the foil reflects back 95 per cent of such radiation, absorbing only 5 per cent. Again, the cheek absorbs about 90 per cent of reflected heat and this increases the temperature of the face.

ROOF CAPPING—Many types of normal roof construction, whether of hardboards, wooden planking or concrete, can be protectively capped using aluminium foil 0·015 mm. thick, soft in temper and embossed, then laid simply on the roofing felt, keeping the bitumen pliable and preventing moisture penetration. Reflecting solar heat keeps the inside cool, while the low emissivity discourages heat loss from the building if it should be warmer inside than out. Protection is given against spark, flame or fire from external sources.

TABLE I—Covering area of aluminium foil sheet

Thickness		Areas covered	
mm.	in.	sq. in./lb.	sq. metres/kilo
0·004	0·00016	64,800	92·50
0·0045	0·00018	57,000	81·30
0·005	0·00020	52,000	73·80
0·006	0·00023	43,400	61·60
0·008	0·00031	32,300	45·80
0·009	0·00035	29,000	41·20
0·010	0·00039	26,000	36·90
0·011	0·00043	23,600	33·60
0·012	0·00047	21,700	30·80
0·015	0·00059	17,500	24·80
0·018	0·00071	14,600	20·70
0·020	0·00079	13,000	18·50
0·025	0·00098	10,500	14·90
0·028	0·00110	9,300	13·22
0·03	0·00118	8,700	12·30
0·035	0·00138	7,400	10·54
0·04	0·00157	6,500	9·25
0·045	0·00177	5,750	8·19
0·05	0·00197	5,200	7·40
0·055	0·00216	4,700	6·70
0·06	0·00236	4,330	6·15
0·065	0·00256	4,010	5·67
0·07	0·00276	3,710	5·27
0·08	0·00315	3,230	4·58
0·10	0·00394	2,600	3·69
0·15	0·00590	1,730	2·46
0·20	0·00787	1,290	1·84

SPEEDBOAT INSULATION—Donald Campbell has pushed the world water speed record forward to approx. 248 miles per hour at Lake Coniston in his *Bluebird*. The lightweight high-strength construction, dictated by the need for more favourable weight/power ratio in this record-breaking craft, has been complemented by the use of aluminium foil for the thermal insulation of the jet pipe.

Exhaust gases at 600-700 deg. C. are emitted by the Metropolitan-Vickers Beryl gas turbine through the tapered exhaust jet pipe at very high speed; the heat of these gases permeating the structure of the boat could rapidly lead to weakening and possible distortion of the framework if the jet pipe were not well insulated.

This insulation consists of a layer of flat aluminium foil wrapped around the tapered jet tube covered by a lattice work of ¼-in. dia. expanded wire coil which is in itself wound with foil. The second layer of corrugated foil covers this lattice work completely. The third layer is of lightly crumpled foil, giving additional intersections of air pockets over the exterior of the corrugated tube. The fourth layer of plain foil rests on and covers the crumpled layer. The whole is encased by a light sheet-metal casing protecting the foil from physical damage.

Basically, the careful disposition of the air space between the tapered jet tube and the outer casing—subdivided by the bright aluminium foil into pockets and layers—greatly reduces the transfer of heat. This combination is an efficient insulation which is clean and light in weight. The use of foil adds as little as 3 oz./ft.^{3} to the weight of a structure, and is durable, unaffected by vibration and is adaptable for temperatures up to about 540 deg. C.

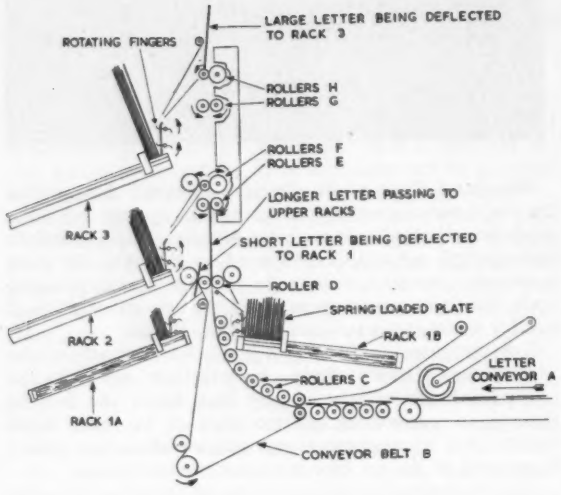
PIPE INSULATION—Cellular asbestos pipe insulation by Bells Asbestos uses an outer covering of foil with inner layers of corrugated asbestos paper interlined with aluminium foil. Sectional pipe insulation, which is being increasingly used, is a clean quick method of lagging pipes of all shapes and sizes (see Fig. 3).

PIPE HEAT TRANSFER—Fig. 2 shows an oil company's experiment originally intended to prevent the exterior insulation coming between the tracing pipe and the process pipe in a sulphonation plant. There has, in addition, been considerable improvement in the heat transfer in the process pipe by conduction along the foil. Filling the spaces with a small amount of crumpled foil has further increased the heat-transfer rate.

Technicians are applying themselves to the use of aluminium foil for a variety of purposes in aircraft, turbine engines and ships, as well as in the accepted field of building. The cost of insulation cannot be considered in isolation; it must be considered on grounds not only of the cost of material but in terms of economy in heating installation and maintenance.

designer's notebook

G.P.O. Letter-segregating Mechanism



AMONG the difficult problems now being tackled by Post Office engineers is the automatic sorting of mail, for which a machine has been developed and is in operation at Southampton. Into an inclined revolving drum, fitted with a series of hinged flaps, the contents of mail bags are taken by a conveyor belt. The thinner packets and letters fall through the flaps and are then conveyed to mechanisms which sort them according to length.

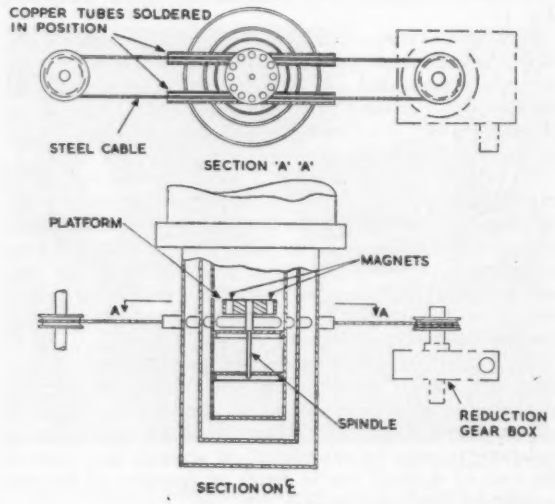
The device illustrated shows the type of mechanism used to accomplish this latter process. Letters from the drum pass along the conveyor A and are then diverted into a vertical path, passing between conveyor belt B and rollers C. If a letter is of the main small category, it passes over the top conveyor roller or over roller D and is stacked by rotating fingers in either rack 1A or 1B.

If, however, the length of the letter is sufficiently great for it to bridge the gap between roller D and rollers E, it is carried on and upwards and then deflected by the next pair of rollers into rack 2. In a similar manner the largest letters which, by reason of their length, can span the distance between rollers E and rollers G are carried upwards to be stacked in rack 3.

Device for Rotating Specimens

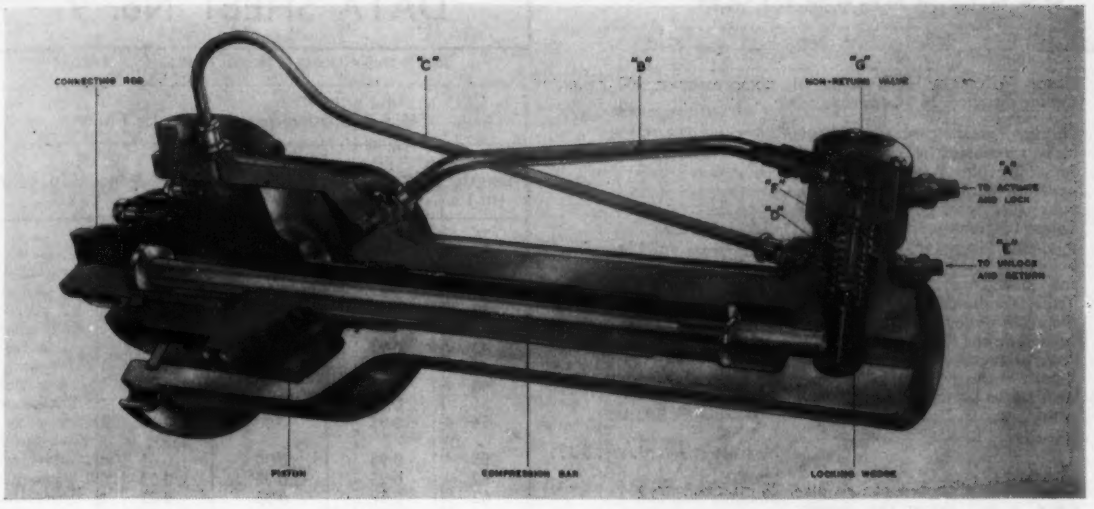
IN recent years magnetic stirrers have come into common use in chemical laboratories. With their use it is possible to stir liquids in enclosed vessels without recourse to mechanical shaft drives and paddles, with the sealing problems these would occasionally present. Instead, a corrosion-protected piece of steel is made to rotate in the liquid by a revolving magnet on the outside of the vessel.

An interesting variant of this principle was suggested for a piece of research apparatus for which the straightforward application of the magnetic stirrer principle was not practicable. In the innermost of three concentric cylindrical vessels it was necessary to provide a small rotating platform. As the innermost cylinder was to be filled with hydrogen gas at −250 deg. C., and the spaces between the other cylinders were vacuum filled, the use of a mechanical drive shaft for the platform would have necessitated a series of small shaft seals in perfect alignment. This would have called for a degree of precision engineering difficult to attain in such a piece of equipment. For various reasons also, a small electric motor housed within the innermost vessel was ruled out.



The solution to the problem is illustrated in the two sectional views, which show the part of the apparatus in which the rotating platform was installed. A light alloy disc platform, into which a series of sintered nickel alloy magnets are pressed, rotates on a central vertical spindle. Passing underneath each side of the platform, and in close proximity to it, are two copper tubes which are dip-soldered into each of the concentric vessels. Through these tubes a steel cable or ball chain passes round the pulleys, one of which is driven by an electric motor through a worm reduction gear. Passage of the cable in opposite directions on each side of the platform in close proximity to the magnets provides the small torque required to cause rotation of the specimens.

The same principle might well be employed to bring about the rotation of a platform in the middle of a vessel containing a liquid. In such a case the tube containing the cable might take the form of a loop passing underneath or around the platform, the ends being soldered or brazed into the side of the vessel. With this method no second pulley would be necessary.



Hydraulic Jack with Mechanical Compression Bar Lock

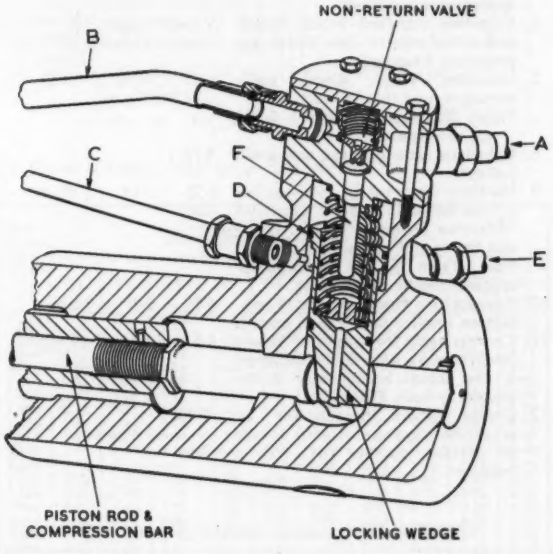
A SAFETY provision in case of hydraulic or pneumatic failure in a jack is made by a recent invention by Rotol Ltd. The invention is suitable for applications where mechanical locking in a pre-loaded condition is required. The makers consider it particularly suitable for use in cases where the controls of a number of valves must be grouped together. An additional advantage is that automatic and remote control could be used.

To actuate and lock the jack, hydraulic fluid pressure is directed by a selector valve (not shown) through the top union A. The fluid lifts the non-return valve and flows along pipe B to the right-hand side of the piston, moving it to the left to close the stop valve (not shown). Meanwhile, fluid from the other side of the piston is exhausted along pipe C, past the annular piston D of the locking wedge and through union E to the low-pressure side of the system. When the stop valve reaches its seat, the fluid pressure in the jack builds up to its maximum, thereby fully loading the compression bar and permitting the spring-loaded locking wedge to be forced fully home behind the compression bar. The stop valve is now firmly locked on its seat in a pre-loaded condition. The load will be maintained by the spring action of the compression bar even if the oil pressure is released.

To unlock and return the stop valve to its "open" position, fluid pressure is directed by a selector valve to the lower union E. From there it passes under the locking wedge piston D and via pipe C to the left-hand side of the jack piston. Fluid on the right-hand side of this piston is trapped by the non-return valve fitted between pipe B and union A.

The fluid pressure under piston D withdraws the locking wedge, but the jack piston is prevented from moving until the trapped oil is released by excess travel of piston D operating through push-rod F to open the non-return valve G. This arrangement ensures that there is no load on the wedge as it is withdrawn and reduces wear of the moving parts.

This invention is, of course, intended for applications where the stroke of the hydraulic ram is fixed, as would be the case where the operation of a valve by hydraulic means is to be carried out. It would appear, however, that with some ingenuity the principle might be extended to cover those numerous applications in which it would be highly desirable to enable such a mechanical safety provision to be made for jacks to lock at any desired length.



CONTRIBUTIONS INVITED

Readers are invited to submit for publication in "Designer's Notebook" details of practical devices and mechanisms which could be of wider application in industry.

Items used in this feature are selected on the basis of their originality, ingenuity and novelty of adaptation for a specific use.

Contributions, which will be paid for, should preferably be about 300 words in length and be accompanied by an explanatory diagram or sketch. The designer's name will be published, unless requested otherwise.

Contributions should be sent to The Editor, "Engineering Materials & Design", Drury House, Russell Street, London, W.C.2.

V-BELT SELECTION

Engineering Materials and Design
DATA SHEET No. 9

EXAMPLE

Motor 7½ h.p. at 1,440 r.p.m. Air compressor at 300 r.p.m. Centre distance, 26 in. approx.

1. Multiply motor horsepower by correction factor in Table 4.	7·5 × 1·3 = 9·75 h.p.
2. Select probable V-belt section and note minimum diameter of smallest pulley (see Table 2).	
3. Calculate from the speed ratios the minimum diameter of the large pulley and select next larger standard size. Any fractional sizes necessary should be confined to the small pulley. If exact speed is needed on the driven pulley, allow one per cent loss for creep of the V-belts in the grooves.	$\frac{5 \times 1{,}440}{300} = 24$ in. Nearest standard say, 25 in.
4. Recalculate exact diameter of small pulley.	$\frac{25 \times 300}{1{,}400} = 5.21$ in. Nearest standard, say, 5·25 in.
5. Check that proposed centre distance is not below the recommended minimum (see under appropriate heading).	26 in. satisfactory
6. Calculate standard V-belt length and actual centre (see under appropriate heading).	V-belt length 105 in. Centre distance 27·7 in.
7. Calculate V-belt speed, using nomogram or this formula. Pulley diameter in inches × 0·262 × r.p.m = spe. ed.	5·25 × 0·262 × 1,440 = = 1,980 f.p.m.
8. Calculate ratio of large and small pulleys	4·76:1
9. Multiply diameter of small pulley by the factor in Table 1 to obtain "Effective Diameter" (DE). Using this figure and belt speed, read off from Table 5 the horsepower transmitted by each V-belt.	5·25 × 1·14 = 5·98 in. (DE)
10. Correct this figure for arc of contact on smaller pulley (See graph).	4·06 × 0·87 = 3·5 h.p.
11. Correct again for length of V-belt (see Table 3). This figure obtained is the actual horsepower transmitted by each V-belt.	3·5 × 1·04 = 3·64 h.p.
12. Divide design horsepower by actual horsepower of each V-belt to obtain number of V-belts required.	$\frac{9.75}{3.64} = 3$ belts

TABLE 1. How to obtain effective diameter (DE)

Speed Ratio	Correction Factor	Speed Ratio	Correction Factor
1·00 to 1·02	1.00	1·22 to 1·27	1·08
1·02 to 1·33	1·01	1·27 to 1·34	1·09
1·03 to 1·05	1·02	1·34 to i·43	1·10
1·05 to 1·08	1·03	1·43 to 1·56	1·11
1·08 to 1·10	1·04	1·56 to 1·81	1·12
1·10 to 1·14	1·05	1·81 to 2·95	1·13
1·14 to 1·17	1·06	2·95 and over	1·14
1·17 to 1·22	1·07		

TABLE 3. Length correction factors for V-belts

Belt length (in.)	½ in. × 5/16 in.	⅝ in. × 7/16 in.	⅞ in. × 9/16 in.	1¼ in. × ¾ in.
26	0·81	—	—	—
31	0·84	—	—	—
32	0·86	—	—	—
35	0·87	0·81	—	—
38	0·88	0·83	—	—
42	0·90	0·85	—	—
46	0·92	0·87	—	—
48	0·93	0·88	—	—
51	0·94	0·89	0·80	—
54	0·95	0·90	0·80	—
55	0·96	0·90	0·81	—
60	0·98	0·92	0·82	—
62	0·99	0·93	0·82	—
64	0·99	0·93	0·83	—
65	1·00	0·94	0·84	—
68	1·00	0·95	0·85	—
70	1·01	0·95	0·85	—
75	1·02	0·97	0·87	—
78	1·03	0·98	0·88	—
80	1·04	0·98	0·88	—
81	1·04	0·98	0·89	—
83	1·04	0·99	0·89	—
85	1·05	0·99	0·90	—
90	1·06	1·00	0·91	—
96	1·08	1·01	0·92	—
97	1·08	1·02	0·92	—
105	1·10	1·04	0·94	—
112	1·11	1·05	0·95	—
120	1·13	1·07	0·97	0·86
128	1·14	1·03	0·98	0·87
134	—	1·09	0·99	0·88
144	—	1·11	1·00	0·90
158	—	1·13	1·02	0·92
162	—	1·13	1·03	0·92
173	—	1·15	1·04	0·93
180	—	1·16	1·05	0·94
195	—	1·18	1·07	0·96
210	—	1·19	1·08	0·96
238	—	1·22	1·11	1·00
268	—	1·25	1·14	1·03
298	—	1·27	1·16	1·05
328	—	—	1·19	1·07
358	—	—	1·21	1·09
382	—	—	1·23	1·11
418	—	—	1·24	1·12
478	—	—	—	1·16
538	—	—	—	1·18
598	—	—	—	1·20
658	—	—	—	1·23

TABLE 2. Recommended belt and pulley sizes for given motor ratings.

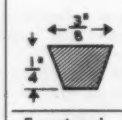
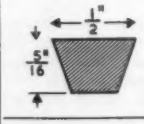
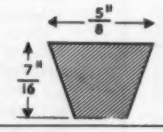
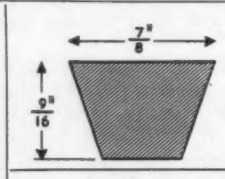
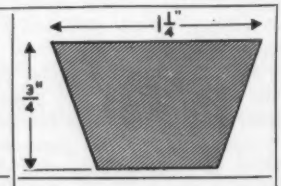
	 Fractional h.p.	 Up to 3 h.p.	 Up to 15 h.p.	 Up to 30 h.p.	 Over 30 h.p.
Recommended min. pulley dia.	2 in.	3 in.	5 in.	9 in.	13 in.
Absolute min. pulley dia.	1½ in.	2·4 in.	4·5 in.	7 in.	—

TABLE 4. Correction factors for special types of load

Machines	Driving Unit: Electric motors: a.c. split phase, a.c. squirrel cage and synchronous, d.c. shunt wound Turbines	Driving Unit: Electric motors: a.c. single phase, a.c. slip ring, d.c. compound wound Steam engines Line shafts Clutch drives
	Service Factors	
Machine tools	1·2	1·4
Printing	1·2	1·4
Metal mining	1·4	1·6
Coal mining	1·4	1·6
Laundry	1·3	1·5
Flour and feed mills	1·4	1·6
Pumps and compressors	1·4	1·6
Woodworking	1·3	1·6
Fans and blowers	1·3	1·6
Pulp and paper	1·3	1·6
Rock crushing	1·6	1·8
Oil field	1·6	1·8
Textile	1·6	1·8
Brick and clay	1·6	1·8

Add to these figures (a) 0·2 for speed-up drives
(b) 0·25 for reversing service or line start motors

ARC CORRECTION FACTORS

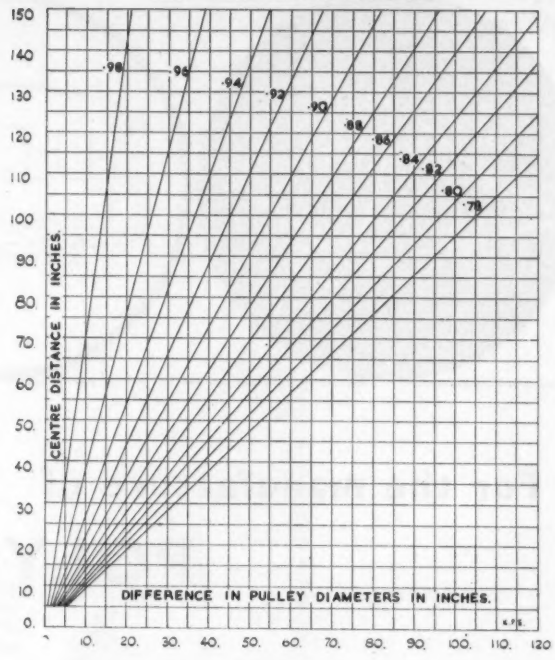


TABLE 5. Increased horsepower ratings (according to Graton & Knight V-belt design brochure)

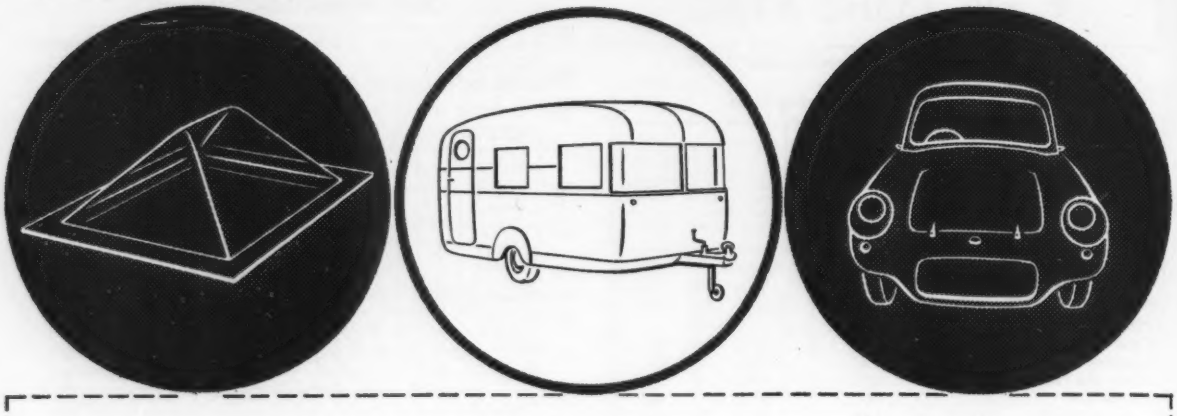
Belt Speed (ft./min.)	⅜ in. × 11/32 in. EFFECTIVE DIAMETER DE (in.)									
	3·2	3·4	3·6	3·8	4·0	4·2	4·4	4·6	4·8	5·0 and over
500	0·60	0·64	0·69	0·73	0·76	0·79	0·82	0·85	0·87	0·89
800	0·85	0·93	1·00	1·06	1·12	1·17	1·22	1·26	1·30	1·33
1,000	1·01	1·10	1·19	1·27	1·34	1·40	1·46	1·51	1·56	1·61
1,200	1·15	1·27	1·37	1·46	1·55	1·62	1·69	1·76	1·81	1·87
1,400	1·28	1·42	1·54	1·65	1·74	1·83	1·91	1·99	2·06	2·12
1,600	1·40	1·56	1·69	1·82	1·93	2·03	2·12	2·21	2·29	2·36
1,800	1·51	1·68	1·84	1·98	2·11	2·22	2·33	2·42	2·51	2·59
2,000	1·61	1·80	1·98	2·13	2·27	2·40	2·51	2·62	2·72	2·80
2,200	1·70	1·91	2·10	2·27	2·43	2·57	2·69	2·81	2·92	3·01
2,400	1·77	2·01	2·22	2·40	2·57	2·72	2·86	2·99	3·10	3·21
2,600	1·84	2·09	2·32	2·52	2·70	2·87	3·02	3·15	3·28	3·40
2,800	1·89	2·17	2·41	2·63	2·82	3·00	3·16	3·31	3·45	3·57
3,000	1·93	2·23	2·49	2·72	2·93	3·12	3·30	3·45	3·60	3·73
3,200	1·96	2·28	2·56	2·81	3·03	3·23	3·42	3·59	3·74	3·88
3,400	1·98	2·31	2·61	2·88	3·11	3·33	3·52	3·70	3·87	4·02
3,600	1·99	2·34	2·65	2·93	3·18	3·41	3·62	3·81	3·98	4·14
3,800	1·97	2·35	2·68	2·97	3·24	3·48	3·70	3·90	4·08	4·25
4,000	1·95	2·34	2·69	3·00	3·28	3·54	3·77	3·98	4·17	4·35
4,200	1·91	2·32	2·69	3·01	3·31	3·57	3·82	4·04	4·24	4·43
4,400	1·86	2·29	2·67	3·01	3·32	3·60	3·85	4·09	4·30	4·49
4,600	1·78	2·23	2·63	2·99	3·31	3·61	3·87	4·11	4·34	4·54
4,800	1·70	2·17	2·58	2·96	3·29	3·60	3·87	4·13	4·36	4·57
5,000	1·59	2·08	2·51	2·90	3·25	3·57	3·86	4·12	4·36	4·59

Belt Speed (ft./min.)	⅜ in. × ½ in. EFFECTIVE DIAMETER DE (in.)									
	5·2	5·4	5·6	5·8	6·0	6·2	6·4	6·6	6·8	7·0 and over
500	1·18	1·23	1·27	1·32	1·36	1·39	1·43	1·46	1·49	1·52
800	1·71	1·79	1·86	1·93	1·99	2·05	2·11	2·16	2·21	2·26
1,000	2·03	2·13	2·22	2·31	2·39	2·46	2·53	2·60	2·66	2·72
1,200	2·33	2·45	2·56	2·66	2·76	2·85	2·93	3·01	3·09	3·16
1,400	2·61	2·75	2·88	3·00	3·11	3·22	3·32	3·41	3·50	3·58
1,600	2·87	3·03	3·18	3·32	3·45	3·57	3·68	3·78	3·88	3·98
1,800	3·12	3·30	3·46	3·62	3·76	3·90	4·02	4·14	4·26	4·36
2,000	3·34	3·54	3·73	3·90	4·06	4·21	4·35	4·48	4·61	4·72
2,200	3·55	3·77	3·98	4·17	4·34	4·51	4·66	4·81	4·94	5·07
2,400	3·74	3·98	4·20	4·41	4·60	4·78	4·95	5·11	5·26	5·40
2,600	3·91	4·17	4·41	4·63	4·84	5·04	5·22	5·39	5·55	5·70
2,800	4·06	4·34	4·60	4·84	5·06	5·27	5·47	5·65	5·83	5·99
3,000	4·19	4·49	4·76	5·02	5·26	5·49	5·70	5·90	6·08	6·26
3,200	4·29	4·61	4·91	5·18	5·44	5·68	5·90	6·12	6·32	6·50
3,400	4·38	4·72	5·03	5·32	5·60	5·85	6·09	6·31	6·53	6·73
3,600	4·44	4·80	5·13	5·44	5·73	6·00	6·25	6·49	6·71	6·92
3,800	4·48	4·85	5·21	5·53	5·84	6·12	6·39	6·64	6·88	7·10
4,000	4·49	4·89	5·26	5·60	5·92	6·22	6·50	6·77	7·02	7·25
4,200	4·48	4·89	5·28	5·64	5·98	6·29	6·59	6·87	7·13	7·37
4,400	4·44	4·88	5·28	5·66	6·01	6·34	6·65	6·94	7·22	7·48
4,600	4·37	4·82	5·25	5·64	6·01	6·36	6·68	6·99	7·27	7·54
4,800	4·27	4·75	5·19	5·60	5·99	6·35	6·68	7·00	7·30	7·58
5,000	4·14	4·64	5·10	5·53	5·93	6·31	6·66	6·99	7·30	7·59

Belt Speed (ft./min.)	½ in. × 13/32 in. EFFECTIVE DIAMETER DE (in.)									
	8·0	8·2	8·4	8·6	8·8	9·0	9·5	10·0	10·5	11·0	11·5	12·00 and over
500	2·25	2·31	2·36	2·42	2·47	2·52	2·63	2·73	2·82	2·91	2·98	3·06
800	3·27	3·37	3·46	3·54	3·63	3·70	3·88	4·05	4·20	4·33	4·45	4·57
1,000	3·90	4·02	4·13	4·24	4·34	4·44	4·66	4·87	5·05	5·22	5·38	5·52
1,200	4·48	4·63	4·76	4·89	5·01	5·13	5·40	5·65	5·87	6·07	6·26	6·43
1,400	5·03	5·20	5·36	5·51	5·65	5·79	6·11	6·39	6·65	6·89	7·10	7·30
1,600	5·55	5·74	5·92	6·09	6·26	6·41	6·78	7·10	7·40	7·67	7·91	8·14
1,800	6·03	6·25	6·45	6·64	6·83	7·00	7·41	7·78	8·11	8·42	8·69	8·95
2,000	6·48	6·72	6·95	7·16	7·37	7·56	8·02	8·42	8·79	9·13	9·44	9·72
2,200	6·90	7·16	7·41	7·65	7·87	8·09	8·59	9·04	9·45	9·82	10·2	10·5
2,400	7·28	7·57	7·84	8·09	8·34	8·58	9·12	9·61	10·1	10·5	10·8	11·2
2,600	7·63	7·94	8·23	8·51	8·78	9·03	9·62	10·2	10·6	11·1	11·5	11·8
2,800	7·94	8·27	8·59	8·89	9·17	9·45	10·1	10·7	11·2	11·6	12·1	12·5
3,000	8·21	8·57	8·91	9·23	9·54	9·83	10·5	11·1	11·7	12·2	12·6	13·1
3,200	8·45	8·83	9·19	9·53	9·86	10·2	10·9	11·6	12·1	12·7	13·2	13·6
3,400	8·64	9·05	9·43	9·79	10·1	10·5	11·2	11·9	12·6	13·1	13·7	14·1
3,600	8·80	9·22	9·63	10·0	10·4	10·7	11·6	12·3	13·0	13·6	14·1	14·6
3,800	8·91	9·36	9·78	10·2	10·6	11·0	11·8	12·6	13·3	13·9	14·5	15·1
4,000	8·97	9·44	9·90	10·3	10·7	11·1	12·0	12·9	13·6	14·3	14·9	15·4
4,200	8·99	9·49	9·96	10·4	10·8	11·3	12·2	13·1	13·8	14·5	15·2	15·8
4,400	8·97	9·49	9·99	10·5	10·9	11·3	12·3	13·2	14·1	14·8	15·5	16·1
4,600	8·88	9·43	9·95	10·4	10·9	11·4	12·4	13·3	14·2	15·0	15·7	16·3
4,800	8·75	9·32	9·86	10·4	10·9	11·3	12·4	13·4	14·3	15·1	15·8	16·5
5,000	8·57	9·16	9·73	10·3	10·8	11·3	12·4	13·4	14·3	15·2	16·0	16·7

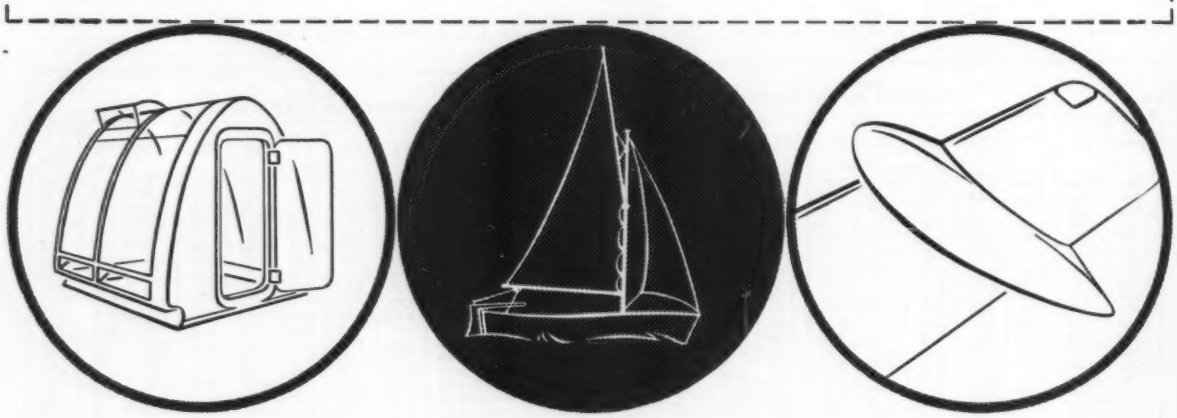
Belt Speed (ft./min.)	1½ in. × ⅞ in. EFFECTIVE DIAMETER DE (in.)									
	12·5	13·0	13·5	14·0	14·5	15·0	15·5	16·0	16·5	17·0 and over
500	4·48	4·69	4·89	5·07	5·24	5·40	5·55	5·69	5·82	5·94
800	6·48	6·82	7·13	7·42	7·70	7·95	8·18	8·41	8·62	8·81
1,000	7·69	8·11	8·50	8·87	9·21	9·52	9·82	10·1	10·4	10·6
1,200	8·81	9·32	9·79	10·2	10·6	11·0	11·4	11·7	12·0	12·3
1,400	9·86	10·5	11·0	11·5	12·0	12·4	12·8	13·2	13·6	13·9
1,600	10·8	11·5	12·1	12·7	13·3	13·8	14·3	14·7	15·1	15·5
1,800	11·8	12·5	13·2	13·9	14·5	15·1	15·6	16·1	16·6	17·0
2,000	12·6	13·4	14·2	15·0	15·6	16·3	16·9	17·4	17·9	18·4
2,200	13·4	14·3	15·2	16·0	16·7	17·4	18·1	18·7	19·3	19·8
2,400	14·1	15·1	16·0	16·9	17·7	18·5	19·2	19·8	20·5	21·1
2,600	14·7	15·8	16·8	17·8	18·6	19·5	20·2	21·0	21·6	22·3
2,800	15·2	16·4	17·5	18·6	19·5	20·4	21·2	22·0	22·7	23·4
3,000	15·7	17·0	18·2	19·3	20·3	21·2	22·1	23·0	23·7	24·5
3,200	16·1	17·5	18·7	19·9	21·0	22·0	22·9	23·8	24·7	25·4
3,400	16·4	17·9	19·2	20·4	21·6	22·7	23·7	24·6	25·5	26·3
3,600	16·7	18·2	19·6	20·9	22·1	23·3	24·3	25·3	26·3	27·2
3,800	16·8	18·4	19·9	21·3	22·6	23·8	24·9	26·0	26·9	27·9
4,000	16·8	18·5	20·1	21·6	22·9	24·2	25·4	26·5	27·5	28·5
4,200	16·8	18·6	20·2	21·8	23·2	24·5	25·8	26·9	28·0	29·0
4,400	16·7	18·5	20·3	21·9	23·4	24·7	26·0	27·3	28·4	29·5
4,600	16·4	18·4	20·2	21·8	23·4	24·9	26·2	27·5	28·7	29·8
4,800	16·1	18·1	20·0	21·7	23·4	24·9	26·3	27·6	28·9	30·1
5,000	15·6	17·7	19·7	21·5	23·2	24·8	26·3	27·6	28·9	30·2

EMD 424 for further information



For the manufacture of

POLYESTER RESINS



PROPYLENE GLYCOL

and a wide range of other glycols

SHELL CHEMICAL COMPANY LIMITED

In association with Petrochemicals Limited and Styrene Products Limited

Divisional Offices:

LONDON: Norman House, 105-109 Strand, W.C.2. Tel: TEMple Bar 4455. MANCHESTER: 144-6 Deansgate. Tel: Deansgate 2411

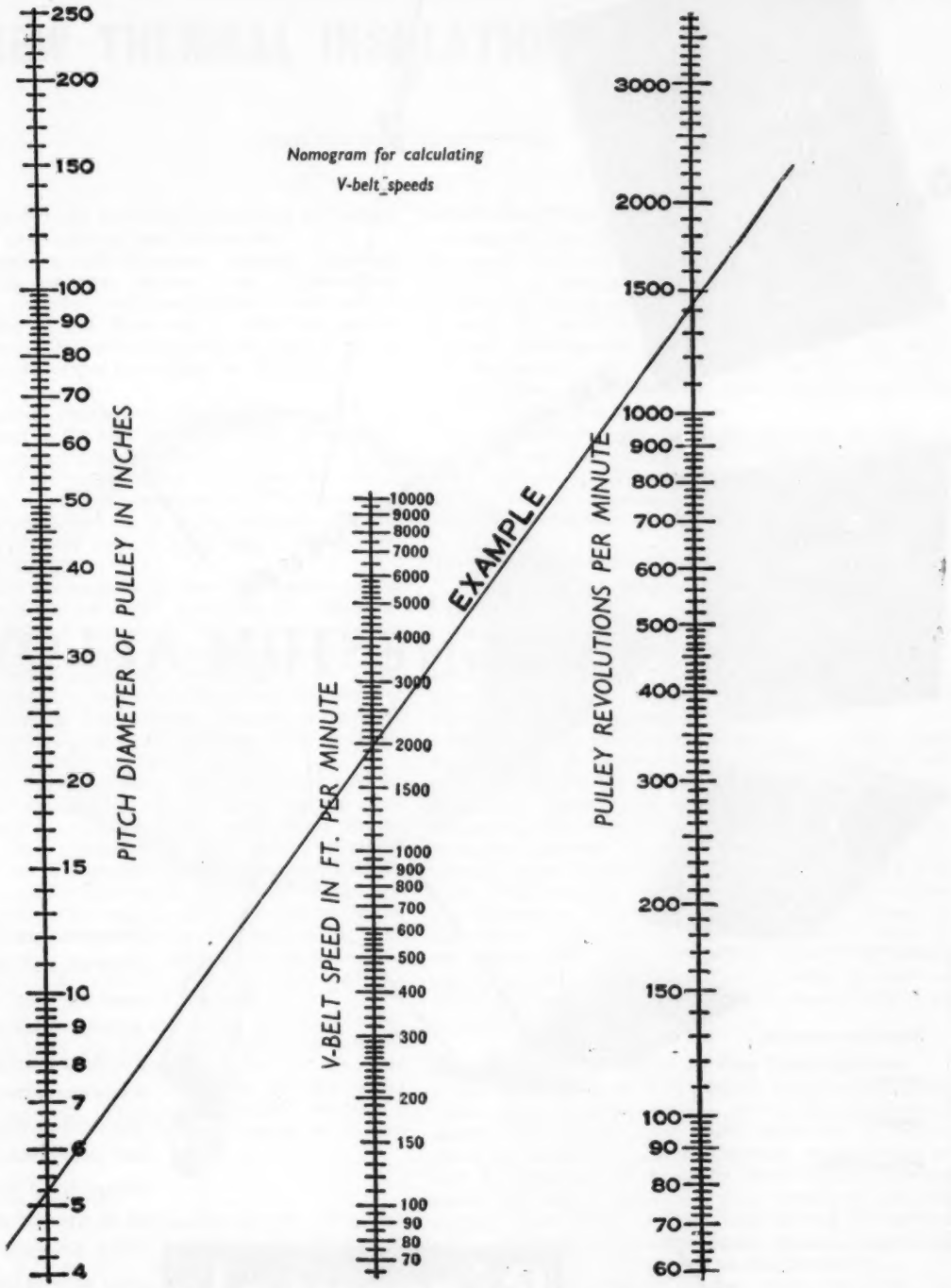
BIRMINGHAM: 14-20 Corporation Street, 2. Tel: Midland 6954-8. GLASGOW: 124 St. Vincent Street, C.2. Tel: Glasgow Central 9561

BELFAST: 16-20 Rosemary Street. Tel: Belfast 26094. DUBLIN: 33/34 Westmoreland Street. Tel: Dublin 72114/5

SHELL

PG1/1

AVAILABLE FROM U.K. PRODUCTION



Nomogram for calculating V-belt speeds

Centre Distances

These should (1) be such that the arc of contact on the small pulley should not be less than 120 deg.;
(2) be not less than the diameter of large pulley,
(3) approximate the sum of the diameters of both pulleys.

Calculation of V-belt Lengths

(a) Multiply the sum (in in.) of the diameters of the two pulleys by 1.57.
(b) Square the difference between the diameters of the two pulleys (in in.), and divide by four times the centre distance (in in.)
(c) Multiply the distance (in in.) between the centres of the shafts by two.

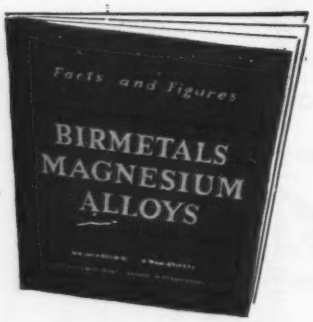
Addition of the results of (a), (b) and (c) will give the pitch length of the V-belt. Pitch diameters of pulleys should be used in the above formula. The length of the V-belt obtained will be a pitch length.

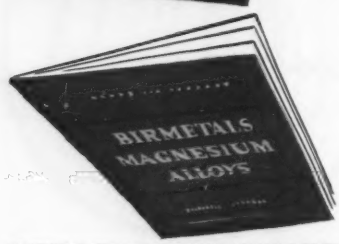
(Data sheets by courtesy of Graton & Knight Ltd.)

EMD 425 for further information

an eye to the future

MAGNESIUM ALLOYS





Please send me booklet

Name .....

Position .....

Business address .....

.....

Is magnesium difficult to weld? Does magnesium corrode in the machine shop? Is magnesium difficult to bend or form?

All these questions, and indeed many more, are answered in this new booklet, which also contains full details of the mechanical properties of magnesium alloys in all wrought forms.

Your reference file is incomplete without this very informative publication. Send for your copy today.

Birmetals

BIRMETALS LIMITED
WOODGATE WORKS
BIRMINGHAM 32

BM 212

NEW THERMAL INSULATION MATERIALS

FROM OUR OWN CORRESPONDENT

TWO new techniques providing a high level of thermal insulation have recently been announced.

One of these, a new inorganic thermal insulating material, fibrous potassium titanate, is now in semi-works production by Du Pont. Maximum service temperature is about 1,200 deg. C. The fibres can be felted into papers, pressed into blocks or used as loose fibrous fill. Curved or odd shapes can be formed by shaping the wet mats prior to drying.

The low thermal conductivity of the fibrous material is due in large part to the high refractive index of the fibres and their dimensions. These qualities serve to block infrared radiation by diffuse reflectance. The fibres, the chemical composition of which is approximately $K_2Ti_6O_{13}$, average 1 micron in diameter and 0·5 to 1 mm. in length after dispersion. Their melting point is 1,370 deg. C. Theoretical density is 200 lb./ft.^{3}

The fibres are produced in the form of irregular masses or lumps. These can be readily processed into blocks or mats of varying bulk densities by felting from water dispersions on to a screen using pressure or vacuum filtration.

The material seems extremely promising for use as insulation in furnaces to reduce insulation bulk and improve operational efficiency. The materials also offer promise for such applications as gaskets and packings, filter materials and electrical insulation at high temperatures.

The inherent thermal stability, good dielectric properties and moisture resistance of silicone insulations are well known in electrical and electronic applications. Recent work by the Dow Corning Corp. has resulted in a new process by which an inorganic filler is used with a solventless silicone resin to produce a hard, rigid encapsulant that has long life at 250 deg. C., good dielectric properties over a wide range of frequencies and temperatures, coefficient of thermal expansion comparable to steel, good physical properties, resistance to water, moisture, chemicals and radiation, and high thermal conductivity.

Of all the filler materials evaluated, zirconium orthosilicate appears to be the most promising for use with the solventless silicone resin. The resin and the filler are applied separately: the filler is poured into the mould around the component and shaken or vibrated, the resin is forced through the filler using vacuum or pressure, and the resin is then cured.

Polyethylene Bullets

High-density (or linear) polyethylene is now being used to form cartridges for specially-designed guns ranging in calibre from 0·22 to 0·3. Instead of the conventional cylindrical shape, the bullets have a triangular cross-section, permitting more ammunition to be loaded in the same size clip or magazine. The cartridges are loaded with standard powder and the slug and primer are metal.

One of the major advantages of polyethylene (Celanese Fortiflex in this case, moulded by the Dardick Corp.) in this application is said to be greater accuracy and more power. On firing, the polyethylene expands against the chamber walls, effectively sealing the barrel and preventing any gas leakage back around the cartridge.

Irradiated Polyethylene Insulates "Wet" Motor

Irradiated polyethylene insulation permits a newly-developed "wet" motor to operate completely submerged in water or a wide variety of chemicals. The motor is not encased, and the insulation is directly exposed to the fluid in which the motor is immersed. The insulation protects windings, bearings and magnetic components, and when used for pumps, seals are eliminated. The first of its type in the U.S.A., the submersible motor was developed by the General Electric Co.

Primarily designed for immersed operation in fresh or salt water and at temperatures up to 320 deg. C., the irradiated polyethylene insulation permits the motor to be used in various chemicals. Primary applications include underwater drive motors and integrated pump motors.

New High-strength Steels

A new series of fine-grained mild carbon steels with high-strength values has been developed by the Great Lakes Steel Corp. In all, four new grades, ranging in yield strength from 45,000 to 60,000 p.s.i., have been made available. The high strength and toughness of the steels (designated GLX-W) are attained through grain refinement resulting from the addition of columbium.

Normally, the mechanical properties of carbon steels depend on the carbon and manganese content and the size of the sections that are hot rolled. Thus, to attain minimum mechanical properties a balance between carbon and manganese content must be maintained. A high carbon and manganese content is usually required to attain yield strengths over 40,000 p.s.i. However with the GLX-W steels, yield strengths can be obtained with lower carbon and manganese contents depending on the amount of columbium added and the hot rolling practice used. At any given carbon and manganese content, by adding columbium the yield strength can be raised as much as 20,000 p.s.i. and the tensile strength by about 15,000 p.s.i. in the mild steel carbon ranges.

Two Acrylics Combine in Car Push-button

The combination of a transparent methyl methacrylate "light piping" component and an opaque, high-impact methyl methacrylate sleeve make decorative as well as functional selector buttons for automatic transmissions for cars. Designed for the American Motor Corp.'s Rambler model, the buttons consist of a clear transparent core and a black sleeve, which is shrink-fitted around the forward end of the button. The entire button projects through the front panel of the selector unit on the dashboard.

The core of the selector buttons, which vary from 3 to 4 in. in length, are moulded in clear acrylic (Plexiglas in this case), which enables them to "pipe" light from a bulb in the selector box for a distance of about 5 in. to the satin-finished faces of the buttons.

The opaque sleeves for the buttons are moulded of a high-impact acrylic (Implex A) which allows them to be shrink-fitted over the transparent core. The opaque sleeves prevent light loss through the sides of the buttons. They also provide a scratch-resistant, shiny surface finish.

WHAT'S NEW IN MATERIALS & COMPONENTS

Steel Screen Cloth

Maxweld screen cloth is a hand-welded mesh produced with a tolerance of only 0·03 in. and is made in hard-drawn steel wire in all sizes from 10 s.w.g wire to ¼-in. dia. bar. It can be supplied in any mesh from ⅛ in. upwards without limit and, if required, for exceptionally heavy work, can be given additional strength by extra arc-welding after manufacture.

An important application is for the accurate grading of coal, iron ore and other materials. Other uses include collapsible and fixed wire-mesh crates, machinery guards, special-purpose containers, etc. Richard Hill Ltd.

EMD 460 for further information

Fireproof Sheet

A new development in the corrugated glass-fibre field is known as Fire Protective F. R. Rilite. After comprehensive tests with this material by the Fire Research Station, it was reported that there was no fire penetration after one hour's exposure, no surface spread of flame and no flaming drops.

Light in weight, strong and durable, this sheeting admits daylight without glare. Rubber Improvements Ltd.

EMD 461 for further information

Rust Inhibitor

Ruskilla rust-inhibiting undercoats are a new development in the anti-corrosive field based upon calcium plumbate. Offering certain advantages over red lead, which has been traditionally used for ferrous metal protection, it is produced in a relatively light shade and has low staining power, thus permitting its use in a variety of tinted paints. Ruskilla is produced in broken white. The illustration shows Ruskilla after application to tar liquor containers at a gas works.

A further advantage of the calcium plumbate is that it offers good adhesion to metal and can, in fact, be used directly over new galvanised iron, without prior treatment of the metal by a mordant. Atlas Preservative Co. Ltd.

EMD 462 for further information

Polyvinyl Sheet

Vybak DVR. 248 is a clear rigid sheet based on a polyvinyl chloride resin. It is suitable for applications requiring a material of high clarity and high transparency to light with excellent dimentional stability.

It is also said to possess extremely good resistance to most chemicals, and also paraffin, petrol and oils, although some reagents may cause discoloration under certain conditions. Also claimed for it are good electrical properties, and that it is odourless, tasteless and non-toxic. Applications include scooter windshields and sidecar glazing, dials and gauge covers, transparent draughting and calculating instruments, etc. It is non-inflammable, but can be formed into simple shapes by warming. Bakelite Ltd.

EMD 463 for further information

Coated Strip

Painted or lacquered steel or aluminium strip, which, it is claimed, will withstand drawing and forming of the most severe nature, is now available in this country. The strip, which is suitable for the production of many types of component or complete article, can be drawn to a depth of 6 in. without impairing the finish. It is bonderised and then finished by roller coating methods with special paints. Many colours are available and the strip is supplied in continuous coils in widths up to 16 in. Paints used are alkyd, vynol and epon-based. Coated Strip Ltd.

EMD 464 for further information

New Tool Steel

Mushet special V.G. high-speed steel is a new development in tool steels. It is a specially balanced tungsten-molybdenum super high-speed steel, containing cobalt for enhanced red hardness with greatly increased carbon and vanadium contents to employ to maximum effect the great intrinsic hardness of vanadium carbide. The resulting combination of high hardness, red hardness, great abrasion resistance and a good measure of toughness impart a suitability for all types of cutting operation.

A performance surpassing that of normal types of high-speed steel is claimed, particularly in cutting the more abrasive materials and those of high work-hardening capacity; tools have a longer life between regrinds and will cut faster.

The steel is now available in the form of lathe and planer tools, toolholder bits, etc., as well as in bars and blanks. Samuel Osborn & Co. Ltd.

EMD 465 for further information

New Silicone Resins

Four new silicone resins have recently been introduced; these are said to provide full silicone protection to the organic component of surface coatings exposed to heat. Success has attended the cold-blending of a silicone and an organic resin, but to secure the fullest heat resistance and protection, heat-blending or co-polymerising is advisable. Resin DP 89, a baking type silicone epoxy co-polymer, is claimed to have excellent adhesion, chemical and solvent resistance and thermal stability. In addition to its surface-coating applications, this co-polymer is likely to be of considerable interest in the electrical field where stability at temperatures up to 200 deg. C. is required. Resin DP 103, a baking-type silicone-organic co-polymer designed for the formulation of heat-resistant paints, is said to withstand temperatures up to 250 deg. C., where hitherto only pure silicone resins have been effective. Resins DP 87 and 88 are new types of silicone intermediates which may be heat-blended with many different organic resins to prepare silicone organic co-polymers. I.C.I. Ltd.

EMD 466 for further information

Toughened Polystyrene

Lustrex T-7 is the latest toughened polystyrene moulding powder, being specially formulated to conform with the physical property requirements of the type 2 toughened polystyrenes of the draft new B.S. specifications for this group of moulding materials.

It is said to possess a toughness which is adequate for all but specialist purposes, and combines with this a surface gloss which is claimed to be unmatched by any other of this type of material. Monsanto Chemicals Ltd.

EMD 467 for further information

Silicone Rubber

A new type of oil-resistant silicone rubber, Silastic LS-53, is now being used for various components in the aircraft industry. Silicone rubber is normally somewhat vulnerable to the swelling action of oils and fuels, particularly the synthetic-type oils used in the modern high-speed aircraft. Silastic LS-53, a

FOR MORE INFORMATION
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

READERS' ADVISORY SERVICE
We shall be pleased to help readers who have difficulty in tracing sources of supply of materials or components.

A NICKEL STORY

Pride of possession, as well as a face is reflected in the mirror finish of really good plating. For sound decorative chromium plating a nickel deposit approximately a hundred times the thickness of chromium is the only foundation which will give years of satisfactory service, against corrosion, rubbing and knocks. Ask Mond about this aspect of the nickel story. Mond have the resources for research and development and supply technical publications for guidance in the choice and use of modern materials.

Enough Nickel for all needs—

Plan ahead with **MOND NICKEL**

THE MOND NICKEL COMPANY LIMITED, THAMES HOUSE, MILLBANK, LONDON, S.W.I

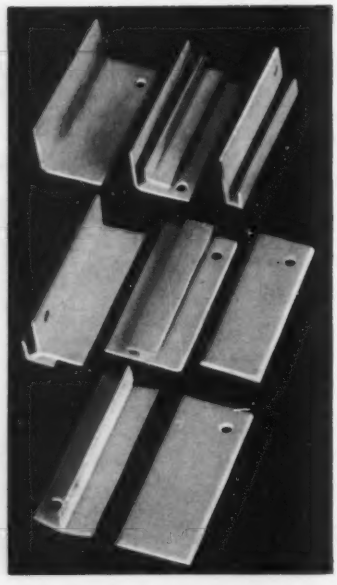
TGA GN22

fluorinated silicone elastomer, is claimed to be notably superior in this respect and to be suitable for use in a wide range of aircraft oils and fuels, including mineral and synthetic di-ester lubricating oils, mineral and silicate ester hydraulic oils, and petrol and kerosene-type engine fuels. It is also said to have excellent low-temperature flexibility characteristics and to function in service at temperatures as low as minus 60 deg. C. Although its resistance to heat ageing is less outstanding than that of standard grades of silicone rubber, it is said that it can safely be used in temperatures of up to 200 deg. C. Dunlop Ltd.

EMD 468 for further information

Thermoplastic Extrusions

An extensive range of rigid p.v.c. extruded edging sections is now available under the name of Melplas. These are produced for a variety of general applications in the form of lips, capping, external and internal angle, angle edging, dividing, as well as additional and more complicated designs which are available



on request. The extrusions are in standard lengths of 8 ft. 6 in., but lengths of up to 14 ft. can be supplied. Colours in the standard range are black, white, cream, blue, red, green and silver. Melwood Thermoplastics Ltd.

EMD 469 for further information

Sintering Powder

A cellulose aceto butyrate sintering powder, known as Cellit, which is said to be suitable for the production of high-gloss coatings on all types of metal objects made from steel, cast steel, cast iron, light metals, copper, etc., by the whirl sintering process. These coatings, in addition to imparting good chemical resistance, are claimed to have good electrical insulation properties and to be very resistant to impact. They are said to be particularly suited to the complete covering of small to medium parts, as well as the flame spraying of smaller objects. R. H. Cole & Co. Ltd.

EMD 470 for further information

Fire-resistant Resin

A new high-gloss, heat-resistant resin is now available in this country. Known as DD Lakk, it is the result of the latest development in cross-linked cyanate polymers. Both the clear and pigmented lacquers produce hard surfaces of exceptional high gloss. The resin is supplied in two separate components, i.e., the alkyd-isocyanate and the polyester.

DD Lakk is claimed to have particularly high adhesion to metal, alloys and all surfaces. Its exceptional abrasion and impact resistance and its ability to withstand high temperatures makes it an ideal protective coating for heavy-duty engines and machinery. The resin can be brushed or sprayed at room temperature. C. J. W. Macaulay.

EMD 471 for further information

Plastics Film

A new plastics film called Videne is now being produced in this country in two film finishes, clear and satin, in gauges from 2 to 7½ mm. Its application as a new polyester laminating film is of interest to many industries.

Laminated to metal, embossed Videne A produces unusual texture effect and at the same time is claimed to offer maximum protection. Popular anodised finishes can be simulated on plain aluminium, steel and many other metals, while colour uniformity can be created at nominal cost.

When laminated to fabrics, it gives a glazed effect, making them easier to clean and giving them improved dimensional stability. On glass fibre fabrics, it is said to increase strength and wearing qualities.

Videne can be laminated and stretch-laminated to paper. Because of its high dielectric strength, it is ideal for insulation application in motors, generators, transformers, condensers and other electrical equipment. Goodyear Tyre & Rubber Co. (G.B.) Ltd.

EMD 472 for further information

New Rubber Compound

Fortiflex is a rubber resin compound which is claimed to have exceptional toughness, resilience, smoothness, lightness and outstanding resistance to impact and abrasion. It cannot crack, splinter or corrode. By the use of special formers, it can be manufactured into various shapes to order.

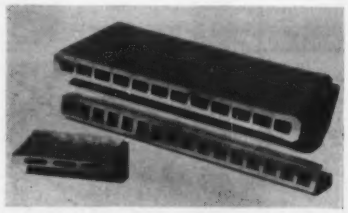
Fortiflex is said to withstand the very roughest treatment and, although somewhat dearer than mild steel, chutes made from it have a substantially longer life because of their good corrosion resistance and their ability to withstand damage caused when clearing blockages, on the rare occasions that this occurs. Dunlop Rubber Co. Ltd.

EMD 473 for further information

Extruded Alloy Sections

A recent development in the manufacture of stress-carrying multi-hole extruded sections in Hiduminium is intended to assist designers to solve many of their heat-exchange problems.

These sections are produced to normal extrusion tolerances in a relatively high strength Hiduminium alloy, which has good resistance to corrosion and so permits the use of a wide variety of cooling or heating media.



They have attractive features for a number of industries. For oil tankers, heat exchangers can be fabricated from these sections and used either for heating or cooling, forming an integral part of the main structure as load-carrying bulkheads. Other uses are the floors of large refrigerators or in fermentation vats, or as heat exchangers for cooling instruments and light equipment. High Duty Alloys Ltd.

EMD 474 for further information

Welded Steel Mesh

Weldmesh is an electrically cross-welded steel mesh, the hard-drawn wires being welded to one another at the intersections. The electrical welding process physically unites the wires at the intersections, producing a construction of maximum strength and rigidity.

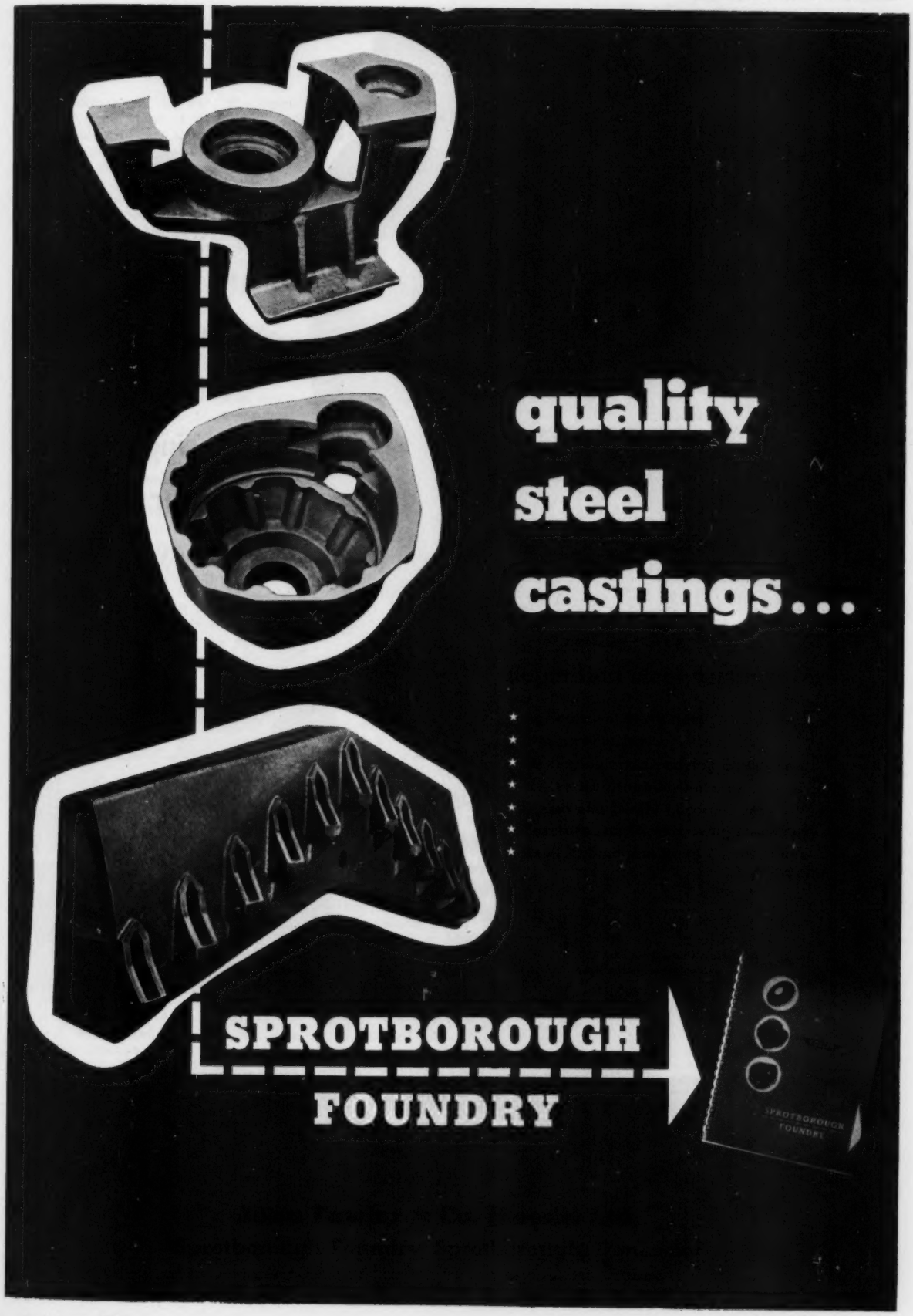
In its appearance, strength and general utility, Weldmesh is claimed to have many practical advantages. It is made in large units and can be cut or shaped to the required size without the wires falling apart. The material forms its own selvages when cut flush. It is supplied in plain, galvanised and hot-dip galvanised finishes.

Some suggested applications are: machine guarding, racking, shelving, partitions, crates, pallets, baskets, window guarding and barriers. B.R.C. Engineering Co. Ltd.

EMD 475 for further information

Reinforced Paper

A reinforced paper product known as Scrimtex, which was developed in the U.S.A., is now available in this country. A glass-fibre or rayon reinforcing scrim has been incorporated into the paper during the wet stage of manufacture; thus it is not a laminate and therefore


quality
steel
castings...
SPROTBOROUGH
FOUNDRY
SPROTBOROUGH FOUNDRY

"achieves the board's objective of offsetting increasing costs by greater efficiency . . . "

Factory Manager

IT is the ambition of every board of directors to reduce operating costs. Only in that way can an effective contribution towards a reduced cost of living result. The industrial, technical and financial press has been unanimous in its praise of our efforts in offsetting increasing production costs by greater efficiency. The new die-line foundry, for the production of pressure die castings, at our Graiseley Hill Works has been described as " . . . well in advance of current practice". The economies that have resulted can become an important contribution in lowering your costs of production.

THE WOLVERHAMPTON DIE CASTING CO. LTD.

GRAISELEY HILL WORKS
WOLVERHAMPTON
Telephone: 23831/6

cannot delaminate in use. The glass-fibre or rayon mesh is said to prevent the spreading of any small hole or tear which may occur in the body paper, and therefore an exceptionally-high tear-resistance is claimed.

Scrimtex remains relatively strong and flexible at temperatures as low as −57 deg. C. and has been used for packing molten resins at temperatures as high as 215 deg. C. William Palfrey Ltd.

EMD 476 for further information

New Polyester Film

Three new grades of Mylar polyester film which can be heat-sealed by normal methods and one which is heat-shrinkable are available in this country.

Mylar is a polyethylene terephthalate film akin to the fibre Dacron in the U.S.A. or Terylene in this country. Consequently, the familiar qualities of these fibres are available in film form. Of these, the most outstanding is toughness. Mylar film is claimed to be the strongest plastic film on the market. Its tensile strength is over 20,000 p.s.i. and impact strength three to four times that of any known film. At the same time it is dimensionally stable and resistant to failure by repeated flexing. Together with its transparency (it transmits more than 90 per cent of incident light) and its high gloss it provides an extremely tough film for many purposes. Durham Raw Materials Ltd.

EMD 477 for further information

Flexible Pipe Coupling

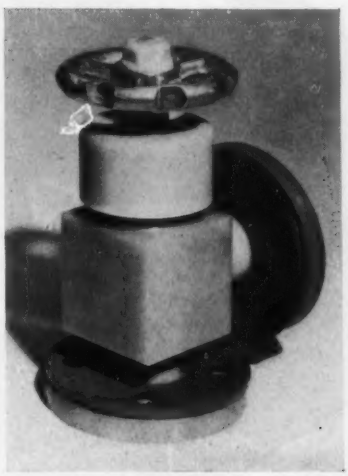
Tube misalignment of up to $\frac{1}{16}$ in. can be accommodated by a new type of coupling which can be installed after the tubes are in place. An axial movement of 0·35 in. is permissible and the couplings can function as slip joints.

The joints eliminate the necessity for metal bellows in pipe runs and require little more than hand tightening to achieve pressure tightness over a large temperature range. They can be used for working pressures from 11-125 p.s.i. and for temperatures from −50 deg. C. to +70 deg. C., and are suitable for lines carrying fuel, oil, hydraulic fluids and air. A full range of standard boss, termination, bulkhead, tee-pipe and 90 deg. elbow pipe couplings, together with screwed spigot and pipe beads, is available to accommodate tubes with outside diameters of $\frac{1}{4}$ in. to 3 in. by $\frac{1}{4}$ in. increments and of $3\frac{1}{2}$ in., 4 in. and 5 in. diameters. A second range covers sizes from $\frac{1}{16}$ in. to $\frac{1}{4}$ in. Aero Controls Ltd.

EMD 478 for further information

Corrosion-resisting Valve

A p.t.f.e. seat is used in a fine adjustment valve suitable for corrosive liquids up to 65 deg. C. Apart from its uses in the mechanical and allied industries, this



valve can be used on board ships in connection with the conversion of sea water. The valve is an addition to a range of corrosion-resisting valves up to 2 in. bore. They are available in flanged ends, and, to a smaller extent, in socket ends for welding into light pressure lines. The range includes fine adjusting valves, pressure relief valves, on/off and non-return valves. They are produced in h.d. polyethylene, rigid p.v.c. and p.t.f.e. Chemical Pipe & Vessel Co. Ltd.

EMD 479 for further information

Electrical Connectors

This new range of connectors is fully interchangeable with the well-known American AN or MS plugs and sockets. Known as the UK-AN range, the new connectors are available as fixed and free units.

Resistance to shock and vibration, coupled with maximum performance, has been obtained with a minimum of weight by using aluminium shells and mouldings of silicone rubber. The use of aluminium bronze for the coupling nut of the free units eliminates the possibility of seizure of threads at high temperatures.

The new connectors have successfully passed humidity tests ranging up to 100 per cent R.H., including conditions producing condensation on equipment. Other tests show that they will function satisfactorily at working temperatures from −65 deg. C. to +190 deg. C. and resist a flame temperature of 1,100 deg. C. for 15 min. while carrying a full rated current. The Plessey Co. Ltd.

EMD 480 for further information

Selector Valve

This valve, the S.817, is a manifold form of pilot valve and in many cases can replace up to ten three-port valves. It is claimed to be particularly useful in applications where there are a number of pneumatic cylinders to be operated automatically in sequence, and can lead to great simplification of controls and interlocks on standard or special-purpose machinery or small plants. It is intended for where four or more pneumatic cylinders are to be operated in sequence.

The valve has ten outlet ports, served by a single inlet and a common exhaust port. Each signal impulse will index the valve one position and a number corresponding to the labelling of the ports will appear below a window on the side of the valve. Martonair Ltd.

EMD 481 for further information

Miniature Instruments

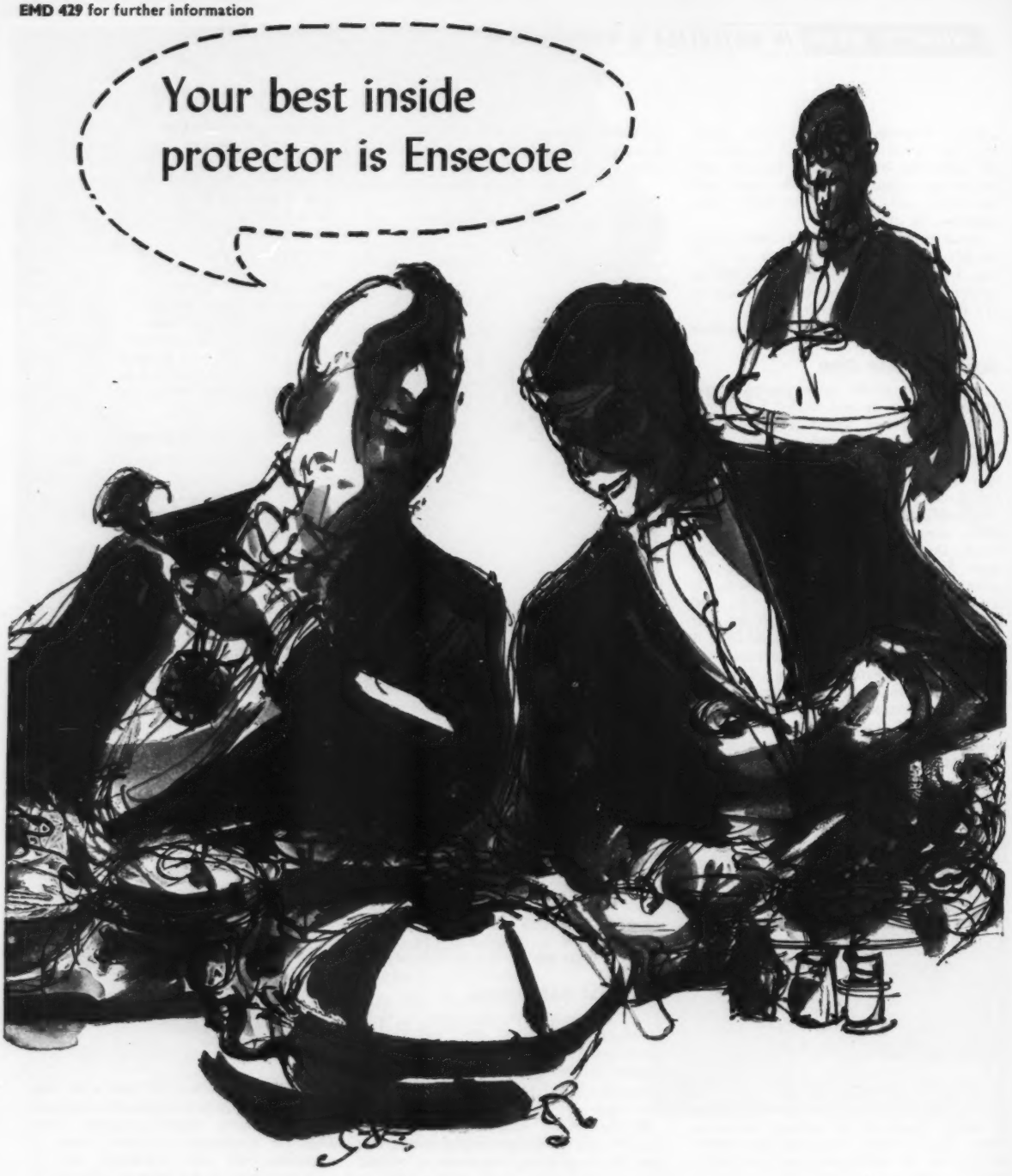
A range of miniature a.c. and d.c. panel instruments of the permanent magnet moving-coil type with rectifiers, for operation on a.c. frequency range of 20-10,000 cycles and with thermocouples for high-frequency applications up to 1 megacycle, is now available. All types are supplied in black Bakelite cases of square, round or rectangular shape. The design incorporates a sintered composite anisotropic magnet with mild-steel pole pieces. Bearing centres are jig-bored in relation to the centre pole of the magnet system, the jewelled bearings being located in the die-cast movement holder. Accuracy of all the instruments in the range conforms to B.S. 89:1954. Laboratory tests show that the instruments can withstand shocks up to 200 g. in any plane. English Electric Ltd.

EMD 482 for further information

Miniature Clutches

Miniature clutches, of only $\frac{1}{4}$ in. dia., primarily developed to provide computer engineers with electro-magnetic couplings for connection in servo drive applications, are now available. An important feature is the high-speed response time, which is of the order of four milliseconds, during which full torque is developed. Three types are available. In the first type one of the coiled connections is to the body, so that this or the mass of the shaft may be used to energise the coil, whose circuit is completed via a single slip ring provided on the body. The clutch is capable of taking shafts up to $\frac{1}{32}$ in. dia. In this type the body is rotated with the rotating parts, but the clutch may be used in applications requiring step-by-step or limited angular rotation. The second type is identical to the first except that the body

EMD 429 for further information



People who pride themselves on their good equipment speak of ENSECOTE in a personal way. ENSECOTE protective plastic linings can be applied almost anywhere to almost anything. They are easily cleaned and sterilised, completely odourless, tasteless—and economical to install because larger vessels can be lined on the spot. ENSECOTE is particularly useful, too, for renovating glass lined tanks. The Dairy, Brewing, Paper and Chemical Industries—and all who own rail and road storage tanks —will find ENSECOTE invaluable as a protection against wastage due to deterioration.

ENSECOTE

Lithcote PLASTIC LININGS

For literature and technical advice write to:
NEWTON CHAMBERS AND CO., LTD.
THORNCLIFFE, NR. SHEFFIELD, ENGLAND
Agents in Belgium, France and Holland:
FOURS LECOCQ ET ATELIERS DE TRAZEGNIES
REUNIS, SA., TRAZEGNIES, BELGIUM

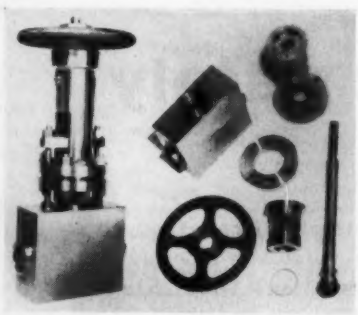
is insulated and electrical connections are made to two slip rings which are provided, e.g., for such applications where the mass may not be used as an electrical conductor. The third type is for operation with the body stationary and accordingly the electrical connections are brought out on two terminals suitable for soldering.

The standard windings for these clutches are for 24 volt d.c. The torque is equal to 8 oz.-in. Special windings are provided when required for up to 60 volts d.c. Kynmore Engineering Co. Ltd.

EMD 483 for further information

High-temperature Valve

The Gyp high-temperature valve A.575, originally designed for special requirements in the atomic field, has been introduced generally to meet the requirements for a valve to handle liquids and gases at temperatures up to 600 deg. C. Sizes from ¼ in. to 2½ in. are available,



and they can be supplied as control valves for metering flow or as normal shut-off valves, with renewable seats and plugs.

Other features can be varied to suit customers' requirements. Intended for use where erosion and corrosion are major problems, the new Sulfinux process is employed in the manufacture. High Pressure Components Ltd.

EMD 484 for further information

Small Toothed Belts

For light, positive drives in business machines, tape recorders and controllers, thin flexible belts having moulded teeth to mesh with grooved pulleys have been introduced. P.V.C. plastisol-coated cotton cord construction is used for applications below 60 deg. C., but for more severe applications rubber and synthetic fibres are used. Graton & Knight Ltd.

EMD 485 for further information

High-pressure Pick-up

A new pick-up allows continuous operation at 320 deg. C. at gauge pressures of from 100-500 p.s.i. The manufacturers consider the applications of these units will be many and varied on account of the high performance and accuracy which they make possible. An all-welded internal construction enables the transducer to function without the need for cooling. A special adaptor can be supplied to extend the operating range to 1,150 deg. C. The Solartron Electric Group Ltd.

EMD 486 for further information

Rotation Pipe Joint

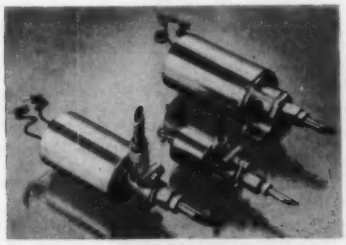
A rotation joint designed for airborne use, which weighs less than 1 lb., is cor-

rosion resistant and can be used between sections or systems which are hinged or rotate about each other, has been introduced. Pressures up to 390 p.s.i. and temperatures from −48 deg. C. to +390 deg. C. can be safely accommodated. The joints are capable of 360 deg. rotation and can be used wherever ram or bleed air must be transferred between hinged or rotated sections, as in boundary layer control ducting, cabin pressure systems, anti-icing systems, missile launching racks, de-humidifying systems for cameras and instrumentation. The stainless-steel ball-bearing design provides low breakaway torque. King Aircraft Corporation.

EMD 487 for further information

Electrically-operated Valves

For use in hydro-pneumatic suspension systems and also for diesel and turbine engine fuel systems, a new range of electrically-operated valves is announced. These are capable of controlling fluid pressures of up to 1,500 p.s.i. The manufacturers claim that the special design of seat and the new valve material employed ensure positive operation and



long life with minimum maintenance. Smiths Jacking Systems Ltd.

EMD 488 for further information

Flow Recorder

A flow recorder suitable for the measurement of high-pressure gas, compressed air, steam, water and other liquids under continuously operating conditions has been developed. The instrument uses the mercury U-tube and float principle and embodies features which eliminate the possibility of mercury being blown into the impulse lines owing to incorrect operation of valves or surges of pressure. The visible width of the chart covers sixteen hours, a roll of chart lasting six weeks. For automatic totalling of flow an electrically-operated integrator can be fitted as an optional extra. Charts can be supplied to meet users' requirements. Walker, Crosweller & Co. Ltd.

EMD 489 for further information

Delay Fuses

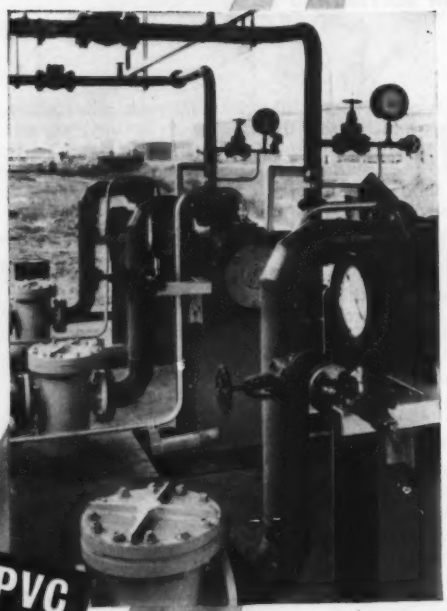
A range of small delay fuses for use in conjunction with the type of small motor used in office, household and factory is announced. Measuring only ¼ in. o.d. and 1¼ in. long, they are fitted with combined slow and quick elements and the manufacturers claim that many surges do not unduly age them. Intended for sub-circuit use, they are available for 250 a.c. max. under supply fuses of 10× rating. They can carry 100 per cent of rating for 1,000 hours, blow at 150 per cent of rating within 1 hour, 200 per cent of rating between 5-60 sec., 300 per cent of rating in five seconds, 500 per cent of rating in three seconds. They are available in ratings from 1-4 amps. A. F. Bulgin & Co. Ltd.

EMD 490 for further information

All-metal Coupling

The Metastream series CN flexible power transmission coupling compensates for shaft misalignment and axial deflection. No thrust is transmitted and there are no moving parts to need attention. The flexible transmission membranes used can be removed from the coupling without disturbing the driving or driven units and can be replaced for a few shillings. The couplings are claimed to be free from corrosion, to require no lubrication and employ no rubber bushes, springs, gears or chains. They are also claimed to be unaffected by climatic conditions and operating temperatures. At present limited to a maximum bore size of 1¾ in., they are available in single and double bank types. Metaducts Ltd.

EMD 491 for further information



High Impact PVC tubing made by Extrudex Ltd, Bracknell, using Geon RA170. Photographs taken at The British Petroleum Co. Ltd Refinery, Isle of Grain.

Geon is a registered trade mark.

GEON RA 170

the High Impact PVC

pipes acid effluent safely

Day and night, night and day, 11,000 feet of shatter-proof piping made with Geon RA170 High Impact PVC carries acid effluent safely away from the BP oil refinery on the Isle of Grain.
Geon RA170 was chosen because it combines outstanding toughness—15-times that of ordinary PVC—with high tensile strength, lightness and resistance to chemicals and solvents. No other PVC so completely satisfies the requirements of piping for the petroleum industry, the chemical industry and all branches of civil engineering.
Please write for Booklet No. 160

BRITISH GEON LIMITED

Geon

Sales and Technical Service
Devonshire House Piccadilly London W1
Telephone: Hyde Park 7321

News of Industry

Dr. L. H. Callendar has opened an independent consultant practice in London, specialising in the economics of research and development, problems of electrochemistry and metallurgy, and works technical control. He was formerly with Crompton Parkinson Ltd., Chloride Batteries, Ford Motor Co. and the British Aluminium Co.

Mr. L. Grainger has been appointed head of the metallurgy division in the U.K. Atomic Energy Authority research group at Harwell in succession to Dr. H. M. Finniston.

Mr. P. M. Brooker has been co-opted to the council of the Institution of Engineering Designers.

Mr. J. R. Richardson has taken over the position of hon. secretary of the north-eastern branch of the Institution of Engineering Designers.

Mr. W. S. Peek, who recently retired as chief draughtsman at the Ministry of Supply, has established a consultancy practice in drawing office management.

Mr. W. G. Vennells, formerly in charge of rubber products development at Ferodo Ltd., has been appointed technical manager of Redfern's Rubber Works Ltd. in succession to the late Mr. R. H. Finer.

Mr. T. V. Duggan has joined the design development department of Lancashire Dynamo & Crypto Ltd.

Mr. J. A. Gay has been appointed patents exploitation officer to the U.K. Atomic Energy Authority in succession to Mr. T. Benson Gyles. About eight inventions a month are developed in the course of atomic energy work and are available for commercial exploitation.

Mr. Geoffrey Gouriet, head of TV group research department at the B.B.C., has resigned to join the board of Wayne Kerr Laboratories Ltd.

Dr. J. G. Pearce, director of the British Cast Iron Research Association, has retired. He is succeeded by **Mr. H. Morrogh**, formerly deputy director.

Mr. Alastair McAlpin has been appointed chief development engineer, J. H. Fenner & Co. Ltd. He will continue to be in charge of engineering research for the company, as well as developing new products.

With the concentration of all aircraft design activities by Vickers-Armstrong (Aircraft) at Weybridge, it has been announced that **Mr. Basil E. Stephenson**, chief engineer, civil aircraft, now becomes director of engineering. **Mr H. H. Gardner**, chief engineer, military aircraft, becomes technical director. **Mr. G. F. H. Hemsley**, assistant chief engineer (aircraft), is to be chief engineer (aircraft) and has also been appointed a special director of the aircraft company. Other new appointments are **Mr. E. S. Allwright**, **Mr. E. E. Marshall** and **Mr. D. Parker** (assistant chief engineers (aircraft)), **Mr. D. James**, chief structural engineer, and **Mr. E. J. Clark**, design manager.

A new organisation known as the International Federation of Operational Research Societies has been set up, with the societies of Britain, France and the U.S.A. as members. Its objects are the development of operational research as a unified science throughout the world. Secretary of the Federation is Sir Charles Goodeve, director of the British Iron and Steel Research Association.

The **Pilkington Group** is to introduce what is claimed to be the first guarantee ever offered with glass in the U.K. It is being introduced in connection with the company's toughened glass doors, marketed under the names of Armourplate and Armourcast, and will be for five years.

The Manchester office of **Durham Raw Materials Ltd.** has been moved to Canada House, 3 Chepstow Street, Oxford Street, Manchester, 1.

Because of the increasing production of goods other than tyres at their factory, the **Goodyear Tyre & Rubber Co.** has formed a new sales division, called General Products Division, which will include industrial rubber products, shoes, films, adhesives and chemical products.

Croda Ltd. have announced the opening of a Scottish branch office at 42 Frederick Street, Edinburgh.

A new 20-minute film has been made by **Permali Ltd.** to show latest techniques used in producing its densified wood laminates. Manufacture and possibilities of its glass-fibre-reinforced laminates and processed p.t.f.e. and cast resin insulation are also described.

Members of the **European Pressure Diecasting Committee** recently made a three-day visit to London to examine technical and economic aspects of diecasting in this country.

G. Gouriet

L. Grainger

J. A. Gay

NEW YEAR HONOURS

Among those in the design fields who received awards in the New Year Honours List are:

C.B.

Mr. W. B. Littler, director-general, scientific research (munitions), Ministry of Supply.

K.B.E.

Mr. G. W. H. Gardner, director, Royal Aircraft Establishment, Farnborough.

C.B.E.

Mr. R. A. Lovell, chief mechanical engineer, Ministry of Transport and Civil Aviation.

O.B.E.

Mr. D. L. Brown, assistant director of engine research and development, Ministry of Supply.
Mr. L. Essen, senior principal scientific officer, National Physical Laboratory.
Mr. F. C. Everett, principal scientific officer, Armaments Prod. Div., Ministry of Supply.
Mr. D. J. Farrar, chief designer, guided weapons, Bristol Aircraft Ltd.
Mr. T. S. Robertson, principal scientific officer, naval construction research establishment, Admiralty.
Major P. L. Teed, deputy director, department of aeronautical research and development, Vickers-Armstrong (Aircraft) Ltd.

M.B.E.

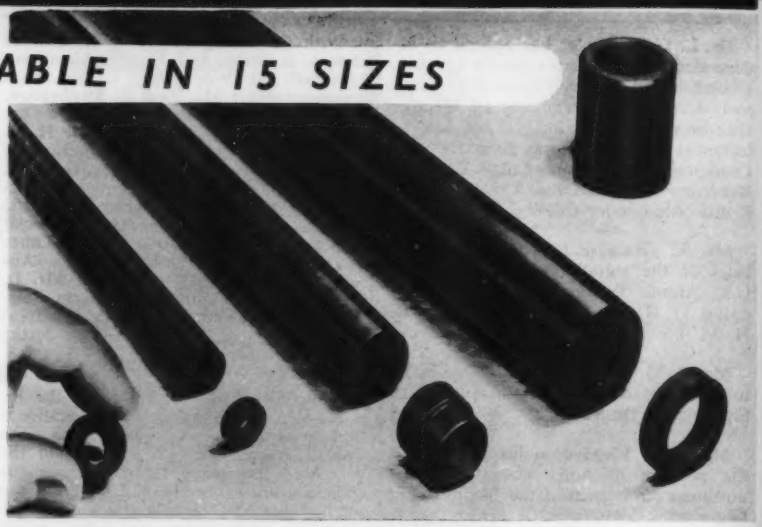
Mr. H. L. Dove, chief draughtsman, Admiralty.
Mr. J. W. Edwards, senior draughtsman, War Office.
Mr. A. C. Emery, chief draughtsman, telecommunication group, Plessey Co.
Mr. I. H. Hogg, senior research planning officer, research and development branch, industrial group, U.K.A.E.A.
Miss M. E. Pollock, secretary, Drawing Office Material Manufacturers and Dealers Association.
Mr. C. Rowley, assistant chief of armament design, Vickers-Armstrong (Eng.) Ltd.
Mr. P. C. Ruggles, senior engineer, English Electric Valve Co.
Mr. E. Shaw, senior draughtsman, Admiralty.
Mr. D. Sleath, chief draughtsman, instrument department, Laurence Scott & Electromotors.
Mr. G. B. Tresilian, lately chemist and metallurgist, Edward Curran Eng. Co.
Mr. D. C. Walker, senior executive engineer, research station, G.P.O.
Mr. F. C. Wells, experimental officer, signals research and development establishment, Ministry of Supply.

Designer's Diary

Feb. 10-11. Electrical Remote Control Co. Ltd. Exhibition of equipment at the Engineering Centre, Birmingham.
Feb. 11. Inst. Prod. Eng. "Epoxy Resins". Municipal Tech. College, Southend. 7.30 p.m.
Feb. 18. Plastics Inst., N.E. section. "Application of Polyester Resins". Eldon Grill, Grey Street, Newcastle. 7 p.m.
Feb. 18. Inst. Prod. Eng. "New Materials, New Techniques". Jas. Watt Memorial Inst., Gt. Charles Street, Birmingham. 7 p.m.
Feb. 25. Inst. Prod. Eng. "Metallic Materials Dev." Town Hall, Weston-super-Mare. 7.30 p.m.

POLYPENCO NYLATRON GS TUBES

NOW AVAILABLE IN 15 SIZES



NYLATRON GS SPECIAL PROPERTIES PROLONG WEARING LIFE OF WORKING PARTS

POLYPENCO "Nylatron" GS is one of the newest compositions available to designers. This special nylon formulation results in a product with proven property advantages.

Greater Rigidity — Parts have higher modulus of elasticity, show less deformation under load than nylon 66. **High Heat Distortion Temperature** — Nylatron GS parts have higher heat distortion temperatures than standard nylon 66. **Low Thermal Expansion** — Coefficient of thermal expansion is approximately 60% of nylon 66. **Low Surface Friction** — When wear parts must run dry, Nylatron GS parts operate without lubrication. **High Wear and Abrasion Resistance** — Part surfaces resist abrasion and demonstrate long wear in contact with metals.

POLYPENCO LTD. 68-70 TEWIN ROAD : WELWYN GARDEN CITY · HERTS.
TELEPHONE: WELWYN GARDEN 5581/3

FOR FABRICATION IN STAINLESS STEEL & NICKEL ALLOYS

A typical W.T.S. job—
All-welded raft fabricated in Monel. Intended for use in the pickling of strip in coils. Load 4½ tons.

tailor-made in Monel...

If the job calls for a nickel alloy or stainless steel—it's a job for W.T.S., who have long been specialists in made-to-measure fabrication and are fully equipped to handle work of any size or complexity.

by the fabrication specialists

WELDING TECHNICAL SERVICES LTD.,
ENGINEERS AND FABRICATORS
HURST MILL, KINGS NORTON, BIRMINGHAM 30
Phone: KINGS NORTON 2360/2555 Grams: WELTEXA, BIRMINGHAM